Rules and Regulations for the Classification of Naval Ships

January 2016

Lloyd's Register

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A guide to the Rules

and published requirements

Rules and Regulations for the Classification of Naval Ships

Introduction

The Rules are published as a complete set; individual Parts are, however, available on request. A comprehensive List of Contents is placed at the beginning of each Part.

Rules updating

The Rules are generally published annually and changed through a system of Notices between releases.

Rules programs

LR has developed a suite of Calculation Software that evaluates Requirements for Ship Rules, Offshore Rules, Special Service Craft Rules and Naval Ship Rules. For details of this software please contact LR.

Direct calculations

The Rules may require direct calculations to be submitted for specific parts of the ship structure or arrangements and these will be assessed in relation to LR's own direct calculation procedures. They may also be required for ships of unusual form, proportion or speed, where intended for the carriage of special cargoes or for special restricted service and as supporting documentation for arrangements or scantlings alternative to those required by the Rules.

January 2016

VOLUME	**1**	**SHIP STRUCTURES**		
		PART	**1**	**REGULATIONS**
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■ *Section 1*
Background

1.1 Lloyd’s Register Group Limited is a registered company under English law, with origins dating from 1760. It was established for the purpose of producing a faithful and accurate classification of merchant shipping. It now primarily produces classification Rules.

1.2 Classification services are delivered to clients by a number of other members subsidiaries and affiliates of Lloyd’s Register Group Limited, including but not limited to: Lloyd’s Register EMEA, Lloyd’s Register Asia, Lloyd’s Register North America, Inc., and Lloyd’s Register Central and South America Limited. Lloyd’s Register Group Limited, its subsidiaries and affiliates are hereinafter, individually and collectively, referred to as ‘LR’.

■ *Section 2*
Governance

2.1 Lloyd’s Register Group Limited is managed by a Board of Directors (hereinafter referred to as 'the Board').

The Board has:

appointed a Classification Committee and determined its powers and functions and authorised it to delegate certain of its powers to a Classification Executive and Devolved Classification Executives;

appointed Technical Committees and determined their powers, functions and duties.

2.2 LR has established National and Area Committees in the following:

Countries:	Areas:
Australia (via Lloyd's Register Asia)	Benelux (via Lloyd's Register EMEA)
Canada (via Lloyd's Register North America, Inc.)	Central America (via Lloyd's Register Central and South America Ltd)
China (via Lloyd's Register Asia)	Nordic Countries (via Lloyd's Register EMEA)
Egypt (via Lloyd's Register EMEA)	South Asia (via Lloyd's Register Asia)
Federal Republic of Germany (via Lloyd's Register EMEA)	Asian Shipowners (via Lloyd's Register Asia)
France (via Lloyd's Register EMEA)	Greece (via Lloyd's Register EMEA)
Italy (via Lloyd's Register EMEA)	

Japan (via Lloyd's Register Group Limited)
New Zealand (via Lloyd's Register Asia)
Poland (via Lloyd's Register (Polska) Sp zoo)
Spain (via Lloyd's Register EMEA)
United States of America (via Lloyd's Register North America, Inc.)

■ *Section 3*
Technical Committee

3.1 LR's Technical Committee is at present composed of a maximum of 80 members which includes:

Ex officio members:

- Chairman and Chief Executive Officer of Lloyd’s Register Group Limited
- Chairman of the Classification Committee of Lloyd’s Register Group Limited

Members Nominated by:

- Technical Committee
- Professional bodies representing technical disciplines relevant to the industry
- National and International trade associations with competence relevant to technical issues related to LR's business

3.2 In addition to the foregoing:

(a) Each National or Area Committee may appoint a representative to attend meetings of the Technical Committee.

(b) A maximum of five further representatives from National Administrations may be co-opted to serve on the Technical Committee. Representatives from National Administrations may also be elected as members of the Technical Committee as Nominated Members

(c) Further persons may be co-opted to serve on the Technical Committee by the Technical Committee.

3.3 All elections are subject to confirmation by the Board.

3.4 The function of the Technical Committee is to consider:

(a) any technical issues connected with LR’s business;

(b) any proposed alterations in the existing Rules;

(c) any new Rules for classification;

Where changes to the Rules are necessitated by mandatory implementation of International Conventions and Codes, or Common Rules, Unified Requirements and Interpretations adopted by the International Association of Classification Societies, these may be implemented by LR without consideration by the Technical Committee, although any such changes will be provided to the Technical Committee for information.

Where changes to the Rules are required by LR to enable existing technical requirements within the Rules to be recognised as Class Notations or Descriptive Notes, these may be implemented by LR without consideration by the Technical Committee, although any such changes will be provided to the Technical Committee for information.

3.5 The term of office of the Chairman and of all members of the Technical Committee is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of office of the Chairman may be extended with the approval of the Board.

3.6 In the case of continuous non-attendance of a member, the Technical Committee may withdraw membership.

3.7 Meetings of the Technical Committee are convened as often and at such times and places as is necessary, but there is to be at least one meeting in each year. Urgent matters may be considered by the Technical Committee by correspondence.

3.8 Any proposal involving any alteration in, or addition to the General Regulations, of Rules for Classification is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification other than the General

Regulations, will following consideration and approval by the Technical Committee either at a meeting of the Technical Committee or by correspondence, be recommended to the Board for adoption.

3.9 The Technical Committee is empowered to:

(a) appoint sub-Committees or panels; and
(b) co-opt to the Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

■ *Section 4*
Naval Ship Technical Committee

4.1 LR's Naval Ship Technical Committee is at present composed of a maximum of 50 members and includes:

Ex officio members:

- Chairman and Chief Executive Officer of Lloyd’s Register Group Limited

Member nominated by:

- Naval Ship Technical Committee;
- The Royal Navy and the UK Ministry of Defence;
- UK Shipbuilders, Ship Repairers and Defence Industry;
- Overseas Navies, Governments and Governmental Agencies;
- Overseas Shipbuilders, Ship Repairers and Defence Industries;

4.2 All elections are subject to confirmation by the Board.

4.3 All members of the Naval Ship Technical Committee are to hold security clearance from their National Authority for the equivalent of NATO CONFIDENTIAL. All material is to be handled in accordance with NATO Regulations or, for non-NATO countries, an approved equivalent. No classified material shall be disclosed to any third party without the consent of the originator.

4.4 The term of office of the Naval Ship Technical Committee Chairman and of all members of the Naval Ship Technical Committee is five years. Members may be re-elected to serve an additional term of office with the approval of the Board. The term of the Chairman may be extended with the approval of the Board.

4.5 In the case of continuous non-attendance of a member, the Naval Ship Technical Committee may withdraw membership.

4.6 The function of the Naval Ship Technical Committee is to consider technical issues connected with Naval Ship matters and to approve proposals for new Naval Ship Rules, or amendments to existing Naval Ship Rules. Where appropriate, Naval Ship Technical Committee may also recognise alternative LR Rule requirements that have been approved by the other Lloyd’s Register Technical Committee as adjunct to the Naval Ship Rules.

4.7 Meetings of the Naval Ship Technical Committee are convened as necessary but there will be at least one meeting per year. Urgent matters may be considered by the Naval Ship Technical Committee by correspondence.

4.8 Any proposal involving any alteration in, or addition to, the General Regulations of Rules for Classification of Naval Ships is subject to approval of the Board. All other proposals for additions to or alterations to the Rules for Classification of Naval Ships, other than the General Regulations, will following consideration and approval by the Naval Ship Technical Committee, either at a meeting of the Naval Ship Technical Committee or by correspondence, be recommended to the Board for adoption.

4.9 The Naval Ship Technical Committee is empowered to:

(a) appoint sub-Committees or panels; and
(b) co-opt to the Naval Ship Technical Committee, or to its sub-Committees or panels, representatives of any organisation or industry or private individuals for the purpose of considering any particular problem.

■ *Section 5*
Applicability of Classification Rules and Disclosure of Information

5.1 LR has the power to adopt, and publish as deemed necessary, Rules relating to classification and has (in relation thereto) provided the following:

(a) Except in the case of a special directive by the Board, no new Regulation or alteration to any existing Regulation relating to classification or to class notations is to be applied to existing ships.

(b) Except in the case of a special directive by the Board, or where changes necessitated by mandatory implementation of International Conventions, Codes or Unified Requirements adopted by the International Association of Classification Societies are concerned, no new Rule or alteration in any existing Rule is to be applied compulsorily after the date on which the contract between the ship builder and shipowner for construction of the ship has been signed, nor within six months of its adoption. The date of 'contract for construction' of a ship is the date on which the contract to build the ship is signed between the prospective shipowner and the ship builder. This date and the construction number (i.e. hull numbers) of all the vessels included in the contract are to be declared by the party applying for the assignment of class to a newbuilding. The date of 'contract for construction' of a series of sister ships, including specified optional ships for which the option is ultimately exercised, is the date on which the contract to build the series is signed between the prospective shipowner and the ship builder. In this section a 'series of sister ships' is a series of ships built to the same approved plans for classification purposes, under a single contract for construction. The optional ships will be considered part of the same series of sister ships if the option is exercised not later than 1 year after the contract to build the series was signed. If a contract for construction is later amended to include additional ships or additional options, the date of 'contract for construction' for such ships is the date on which the amendment to the contract is signed between the prospective shipowner and the ship builder. The amendment to the contract is to be considered as a 'new contract'. If a contract for construction is amended to change the ship type, the date of 'contract for construction' of this modified vessel, or vessels, is the date on which the revised contract or new contract is signed between the Owner, or Owners, and the shipbuilder. Where it is desired to use existing approved ship or machinery plans for a new contract, written application is to be made to LR. Sister ships may have minor design alterations provided that such alterations do not affect matters related to classification, or if the alterations are subject to classification requirements, these alterations are to comply with the classification requirements in effect on the date on which the alterations are contracted between the prospective owner and the ship builder or, in the absence of the alteration contract, comply with the classification requirements in effect on the date on which the alterations are submitted to LR for approval.

(c) All reports of survey are to be made by surveyors authorised by members of the LR Group to survey and report (hereinafter referred to as 'the Surveyors') according to the form prescribed, and submitted for the consideration of the Classification Committee.

(d) Information contained in the reports of classification and statutory surveys will be made available to the relevant owner, National Administration, Port State Administration, P&I Club, hull underwriter and, if authorised in writing by that owner, to any other person or organisation.

(e) Notwithstanding the general duty of confidentiality owed by LR to its client in accordance with the LR Rules, LR clients hereby accept that, LR will participate in the IACS Early Warning System which requires each IACS member to provide its fellow IACS members and Associates with relevant technical information on serious hull structural and engineering systems failures, as defined in the IACS Early Warning System (but not including any drawings relating to the ship which may be the specific property of another party), to enable such useful information to be shared and utilised to facilitate the proper working of the IACS Early Warning System. LR will provide its client with written details of such information upon sending the same to IACS Members and Associates.

(f) Information relating to the status of classification and statutory surveys and suspensions/withdrawals of class together with any associated conditions of class will be made available as required by applicable legislation or court order.

(g) A Classification Executive consisting of senior members of LR's Classification Department staff shall carry out whatever duties that may be within the function of the Classification Committee that the Classification Committee assigns to it.

Section 6
Ethics

6.1 No LR Group employee is permitted under any circumstances, to accept, directly or indirectly, from any person, firm or company, with whom the work of the employee brings the employee into contact, any present, bonus, entertainment or honorarium of any sort whatsoever which is of more than nominal value or which might be construed to exceed customary courtesy extended in accordance with accepted ethical business standards.

Section 7
Non-Payment of Fees

7.1 LR has the power to withhold or, if already granted, to suspend or withdraw any ship from class (or to withhold any certificate or report in any other case), in the event of non-payment of any fee to any member of the LR Group.

Section 8
Limits of Liability

8.1 When providing services LR does not assess compliance with any standard other than the applicable LR Rules, international conventions and other standards agreed in writing.

8.2 In providing services, information or advice, LR does not warrant the accuracy of any information or advice supplied. Except as set out herein, LR will not be liable for any loss, damage or expense sustained by any person and caused by any act, omission, error, negligence or strict liability of LR or caused by any inaccuracy in any information or advice given in any way by or on behalf of LR even if held to amount to a breach of warranty. Nevertheless, if the Client uses LR services or relies on any information or advice given by or on behalf of LR and as a result suffers loss, damage or expense that is proved to have been caused by any negligent act, omission or error of LR or any negligent inaccuracy in information or advice given by or on behalf of LR then LR will pay compensation to the client for its proved loss up to but not exceeding the amount of the fee (if any) charged for that particular service, information or advice.

8.3 LR will print on all certificates and reports the following notice: Lloyd's Register Group Limited, its affiliates and subsidiaries and their respective officers, employees or agents are, individually and collectively, referred to in this clause as ‘Lloyd's Register’. Lloyd's Register assumes no responsibility and shall not be liable to any person for any loss, damage or expense caused by reliance on the information or advice in this document or howsoever provided, unless that person has signed a contract with the relevant Lloyd's Register entity for the provision of this information or advice and in that case any responsibility or liability is exclusively on the terms and conditions set out in that contract.

8.4 Except in the circumstances of section *8.2* above, LR will not be liable for any loss of profit, loss of contract, loss of use or any indirect or consequential loss, damage or expense sustained by any person caused by any act, omission or error or caused by any inaccuracy in any information or advice given in any way by or on behalf of LR even if held to amount to a breach of warranty.

8.5 Any dispute about LR services is subject to the exclusive jurisdiction of the English courts and will be governed by English law.

Section

■ *Introduction*

Definition of Naval Class

Naval ship Classification may be regarded as the development and worldwide implementation of published Rules and Regulations, which, in conjunction with proper care and conduct on the part of the Owner, will provide for:

(a) the structural strength and the watertight integrity of all essential parts of the hull and its appendages; this includes compliance with a suitable damage stability standard accepted by Lloyd's Register (hereinafter referred to as 'LR');
(b) the safety and reliability of engineering systems essential for propulsion, steering and other Mobility and/or Ship Type-specific functions, *see Vol 2, Pt 1, Ch 1, 3 Engineering system designation*;
(c) the operation and functioning of associated systems installed for operational requirements relating to the ship type, *see Vol 2, Pt 1, Ch 1, 3 Engineering system designation*; and
(d) the effectiveness of other defined features and systems which have been built into the ship in order to establish and maintain basic conditions on board whereby appropriate stores, fuels, equipment and personnel can be safely carried whilst the ship is at sea, at anchor, or moored in harbour.

A naval ship is said to be in Class when the Rules and Regulations which pertain to it have been complied with, or compliance, equivalent to the Rules, has been ascertained.

LR maintains these provisions by way of periodical visits by its Surveyors to the ship as defined in the Regulations in order to ascertain that the vessel currently complies with those Rules and Regulations. Records of any defects found, or modifications carried out, between visits by LR Surveyors, which may affect Classification, are to be maintained. Any defects found are to be reported to LR with the minimum of delay. The records will form the basis of remedial action, where necessary, for maintenance of Class.

Military Distinctions

Military Distinction notations are awarded by LR as shown in *Vol 1, Pt 4 Military Design and Special Features* of these Rules. LR requires demonstration of the capability of the ship to withstand specified hostile military action without loss of capability. It is the responsibility of the navy or designer to specify and quantify the weapon performance and scenarios to be studied. A Military Distinction notation is awarded by LR on the basis that the assessment presented has been conducted in accordance with agreed procedures and the ship constructed in a manner that reflects the design requirements.

LR is to be informed of any incident of the ship sustaining damage. Such ships are to be made available for survey thereafter at the earliest possible opportunity.

Options

The handling of safety matters such as ship's stability, life-saving appliances, pollution prevention arrangements and structural fire protection, fire detection and extinction arrangements is the prerogative of the Owner and his delegated Naval Administration. However, where these matters are delegated to LR they will be undertaken in accordance with agreed procedures and appropriate class notations will be assigned and entered into the vessel's Classification record.

Transfer of Information

To achieve naval class it is imperative to ensure that communication between LR, the Owner, Naval Administration, Prime Contractor, designer and Builder is effective. In designing, building and maintaining a ship to class, it is essential that liaison between the various parties involved is assured. In particular, formal written contracts are essential for commercial reasons between the contractors, but an additional responsibility rests with all participants to ensure that naval class leads to a transparency of information during construction and thereafter.

■ *Section 1* Conditions for Classification

1.1 Framework of Classification

1.1.1 The Rules and Regulations for the Classification of Naval ships, hereinafter referred to as the Rules, are applicable to those types of ship which are defined in *Vol 1, Pt 1, Ch 2, 2.1 Applicable ship types*

1.1.2 The Rules do not, unless stated or implied in the Class notation, provide for special distributions or concentrations of loading associated with the operation of the ship. LR may require additional strengthening to be fitted in any ship which may be subjected to severe stresses due to particular features in the design or operation, or where it is desired to make provision for exceptional loading conditions. In such cases particulars and details of the required loadings are to be submitted for consideration.

1.1.3 Compliance with the Rules does not relieve the designer of their responsibilities for compliance with the Owner's and Naval Administration's requirements for the overall design features, in-service performance, certification requirements, and standards to which the ship is to be built.

1.1.4 New ships built in accordance with the Rules, or in accordance with requirements equivalent thereto, will be assigned a Class and will continue to be classed so long as they are found, upon examination at the prescribed surveys, to be maintained in accordance with the requirements of the Rules.

1.1.5 In addition to confirming compliance with the Rules, LR will, in conjunction with the Naval Administration, require to be satisfied that the ship is suitable for the geographical or other limits or conditions of the service requested.

1.1.6 Preparations required to permit a ship with a service area restriction specifying some service limitation to undertake duties that take the ship beyond the specified service restriction, either from port of building to its service area or from one service area to another, are to be in accordance with arrangements agreed by LR prior to the voyage.

1.1.7 Any damage, defect, breakdown or grounding, which affect the conditions for which a Class has been assigned, must be reported to LR. (Note that some ships have a grounding condition included for Class).

1.1.8 Where LR is acting on behalf of the Naval Administration, any relevant requirements of the Naval Administration are to be identified and advised to LR in writing.

1.1.9 It is a requirement of classification that stability and subdivision arrangements are to comply with and be maintained in compliance with a specified standard(s). The specified standard(s) and ongoing certification regime are to be notified to LR by the Naval Administration in writing. Where the Naval Administration, or its recognised organisation, approves the arrangements for compliance with the required stability and subdivision standards, a copy of the following documentation is to be submitted:

- approval documentation issued by the Naval Administration stating that arrangements have been examined against the required standard and are acceptable.
- accepted arrangements of openings, closing appliances, vents, etc. such that the limits of the watertight integrity may be defined at the design draught. From these limits the pressure heads for watertight structure and watertight/weathertight closing requirements for openings, etc. can be identified.

Alternatively, where requested, LR will approve the arrangements against the agreed standard(s).

1.1.10 It is a requirement of classification that fire safety arrangements are to comply with and be maintained in compliance with a specified standard(s). The specified standard(s) and ongoing certification regime are to be notified to LR by the Naval Administration in writing. Alternatively, where requested, LR will approve the arrangements against the agreed standard(s).

1.1.11 It is a requirement that where a vessel operates aircraft, it is classed in accordance with the requirements of the **AIR** notation defined in *Vol 1, Pt 4, Ch 2, 10 Aircraft operations* for the landing, manoeuvring and parking areas.

1.1.12 It is a requirement that, where the vessel has fitted on board lifting appliances which are considered by LR to be necessary for it to fulfil its Ship Type role (e.g. aircraft lifts on aircraft carriers, landing platform dock stern ramp) and that there are no alternative means of operation, the lifting appliance(s) are to be designed, built and surveyed in accordance with LR's *Code for Lifting Appliances in a Marine Environment, November 2015* (LAME) and the notation **LA** is to be assigned. This notation will be assigned in association with a Register of Lifting Appliances listing the appliances covered. The Register of Lifting Appliances is the responsibility of the Owner. Elsewhere, classification of lifting appliances is optional and may be assigned at the request of the Owner on compliance with the appropriate requirements, *see Vol 1, Pt 1, Ch 2, 3.9 Machinery and Engineering Systems notations 3.9.1*.

1.1.13 It is a requirement of classification that magazine safety arrangements are to comply with and be maintained in compliance with a specified standard(s). The specified standard(s) and ongoing certification regime are to be notified to LR by the Naval Administration in writing. LR will provide advice on this aspect at the request of the Owner/Naval Administration.

1.1.14 Where an onboard computer system having longitudinal strength capability, which is required by the Rules, is provided on a new ship, or newly installed on an existing ship, then the system is to be certified in respect of longitudinal strength in accordance with LR's document entitled *Approval of Longitudinal Strength and Stability Calculation Programs*, *see also Vol 1, Pt 5, Ch 4, 5 Residual strength hull girder loads*

1.2 Application

1.2.1 Except in the case of a special directive by LR no new Regulation or alteration to any existing Regulation relating to the character of Classification or to Class notations is to be applied to existing ships.

1.2.2 At the discretion of LR, ship types which are specifically covered by LR*Rules and Regulations for the Classification of Ships* or other LR Rules and Regulations for Classification may be considered for classification in accordance with these Rules and Regulations. *See Vol 1, Pt 1, Ch 2, 9.1 General 9.1.1*.

1.3 Interpretation of the Rules

1.3.1 The interpretation of the Rules is the sole responsibility, and at the sole discretion, of LR.

1.4 Owner's responsibilities

1.4.1 The Owner is to give LR Surveyors every facility and necessary access to carry out their survey duties. The Owner should familiarise himself with the relevant LR Rules and, where appropriate, arrange that all sub-contractors, suppliers of components, materials or equipment do the same.

1.4.2 The survey procedures undertaken by LR when providing services are on the basis of periodical visits involving both monitoring and direct survey. LR's Surveyors may not be in continual attendance. As construction, outfitting and refitting are continuous processes, the Builder has the overall responsibility to his client to ensure and document that the requirements of the Rules, approved drawings and any agreed amendments made by the attending LR Surveyors, have been complied with.

1.4.3 Where the Owner/Naval Administration identifies standards, conducts audits or issues certificates, and the responsibility has not been delegated to LR, LR is to be advised of the identity of the Naval Administration and is to be furnished with all appropriate standards and to have full access to the Naval Administration at all times.

1.5 Documentation

1.5.1 It is acknowledged that the Owner may wish to retain the originals of Certificates issued by LR, however, naval ships are required to carry the following documentation on board so that the attending surveyor is able to carry out his duties (certified copies of Certificates are acceptable):

(a) Endorsable Certificate of Class.
(b) C11(N) – Record of watertight and weathertight closing arrangements.
(c) Approved Stability information and damage control plan and the following as applicable.
(d) Lifting Appliances Certificate.

(e) Pollution record of equipment.

(f) Tonnage Certificate.

(g) Safety Equipment record of equipment.

(h) Fire control plan.

1.6 Pre-Contract and Through-Life advice

1.6.1 LR will provide advice on the potential conditions of Classification for a naval ship, so that the Owner may specify design, construction and operation parameters that satisfy the requirements for Classification whilst being consistent with the intended application. A number of optional matters can be incorporated into the Conditions for Classification of the ship, *see Vol 1, Pt 1, Ch 2, 3.10 Other notations 3.10.9* and *Vol 1, Pt 1, Ch 3, 2.4 Other notations*. LR will also advise on Alterations and Additions and other matters which may affect the Conditions for Classification, and to liaise with the Owner on any other matter of concern for the purpose of assisting the Owner in establishing the parameters applicable to the ship's operational needs.

■ *Section 2*
Scope of the Rules

2.1 Applicable ship types

2.1.1 The Rules are applicable to naval ships designed and constructed for the purpose of carrying and operating naval systems. For the purposes of Classification, naval ships can be grouped into five categories as follows:

(a) **NS1 ships**

This category covers ships used for the deployment of aircraft or equipment and ships which may be used as centres of command. Designed for world wide operation and usually supported by ships from the NS2 category.

Typically it will cover ships above 140 m in length with a deep displacement of 10000 tonnes or more. It will include aircraft carriers, helicopter and amphibious support ships, and assault ships.

(b) **NS2 ships**

This category covers ships used to defend NS1 ships as part of a task force or act as independent units. They may have a variety of sole or multiple roles including air defence, anti submarine, sea defence, shore support and will be designed for world wide operation.

Typically it will cover ships of length of 70 m to 140 m with displacements of 1300 tonnes to 20000 tonnes. NS2 ships may be described as cruisers, frigates, destroyers, corvettes or similar.

(c) **NS3 ships**

This category covers ships that have a front line role but are not covered by the above descriptions. This category includes a variety of ships typically below 1500 tonnes displacement. They may operate independently or as part of a task force and are usually designed and constructed for specific roles such as mine sweeping, beach landings, coastal defence or fast patrol duties. A restricted service area may be specified.

(d) **NS(SR) ships**

This category covers auxiliary naval ships used for the support of civil and naval operations. They may have a variety of roles including the movement of military and other personnel, ammunition, vehicles, stores and fuels and the transfer of such to other naval ships. They do not have a defined military role but may have a limited self-defence capability. In general, the ships will comply with LR's Rules for Ships and any relevant requirements in *Vol 1, Pt 1, Ch 3, 17 Classification of ships built under survey to LR Classification Rules and Regulations other than LR Naval Ship Rules and Regulations* and satisfy as far as practicable the requirements of the International Conventions applicable to the ship type. Any deviation from the applicable International Convention requires agreement with the National Administration. A Design and Operating Scenario Statement declared by the Owner stating the role of the ship in terms of the carriage of equipment, personnel, stores and fuels is to be acceptable to LR.

(e) **NS(SSC) ships**

This category covers ships that have been designed and built using the LR *Rules and Regulations for the Classification of Special Service Craft* (hereinafter referred to as the Rules for Special Service Craft). This category is limited to ships typically below 1500 tonnes displacement or 110m length. They do not have a defined military role but may have a limited self-

defence capability and are usually designed and constructed for constabulary purposes such as coastal defence or patrol duties. In general, ships are required to comply with International Conventions applicable to the ship type. Deviations from applicable International Conventions require agreement with the Navy or Naval Administration and where applicable the National Administration. Where an **NS(SSC)** notation is applicable, the requirements of the Rules for Special Service Craft, *Pt 1, Ch 2 Classification Regulations* are not applicable and the requirements of this Chapter are to be applied.

There are special requirements for hovercraft, mine-sweepers, landing ships, which are to be designed in accordance with the appropriate Sections of relevant LR's Rules and Regulations.

2.2 Definitions

2.2.1 For the purpose of the Rules and Class notations, the definitions given in *Vol 1, Pt 1, Ch 2, 2.2 Definitions 2.2.2* to *Vol 1, Pt 1, Ch 2, 2.2 Definitions 2.2.14* will apply.

2.2.2 **Clear water.** Water having sufficient depth to permit the normal development of wind generated waves.

2.2.3 **Designer.** The organisation which provides the design and constructional plans.

2.2.4 **Fetch.** The extent of clear water across which a wind has blown before reaching the ship.

2.2.5 **Maximum speed.** Maximum speed is the speed, in knots, achieved at the maximum continuous power for which the ship is certified in smooth water.

2.2.6 **Mono-hull ship.** A mono-hull ship is a ship whose single hull may be of displacement form or of a semi-planing or planing form subject to some support by hydrodynamic lift.

2.2.7 **Naval Administration.** An authority or authorities nominated by the Owner responsible for providing regulation associated with procurement and support of the ship. The Naval Administration may also be responsible for identifying appropriate standards, auditing and certification. The Naval Administration could be a Government department, Statutory Authority, LR or an independent organisation with appropriate standing. In the absence of a clearly defined Naval Administration, LR will refer to the Owner.

2.2.8 **Navy.** The operator of the ship. The Navy may also be the Owner.

2.2.9 **Owner.** Generally, this will be the government department responsible for naval procurement and support. In certain circumstances, the Navy may operate ships chartered from other Owners, in which case the Owner as defined in these regulations is to be agreed with LR on a case by case basis.

2.2.10 **Client.** LR’s point of contact with the organisation contracting it to undertake work.

2.2.11 **Operational envelope**. The operational envelope will be provided by Lloyd’s Register as an Annex to the Classification Certificate and defines limits of the vessel’s service in terms of operational speeds, wave heights, displacements, service area and time required to seek refuge where this is required.

2.2.12 **Reasonable weather.** Reasonable weather is defined as wind strengths of force six or less on the Beaufort scale, associated with:

(a) Sea states within the operational envelope which are sufficiently moderate to ensure that green water is taken on board at infrequent intervals only or not at all.
(b) Motions such as do not impair the efficient operation of the ship.

2.2.13 **Sheltered water.** Water where the fetch is six nautical miles or less.

2.2.14 **Stability information.** Documents required for stability certification.

2.2.15 **Standard.** A set of appropriate requirements and/or criteria that are to be agreed by the Naval Administration prior to the plan appraisal stage.

2.2.16 **Concept of Operations**. The Concept of Operations (ConOps) is a statement of an Owner’s intentions for the operation of the ship. The ConOps describes the ship’s intended service in terms of purpose and function and is to include, but not be limited to, information on the following: crewing, operational speeds, wave heights, displacements, service area, temperatures, motions, aircraft and boat operations; arrangements under reasonably foreseeable, normal and abnormal conditions. The ConOps is to be provided by the Owner. LR may accept alternative documents where these provide the information which would be included within the ConOps, in such cases the relevant sections providing the information required to provide equivalence with the ConOps are to be identified.

2.2.17 **System Operational Concept.** A System Operational Concept is a description of the intended operation of each of the major ship systems, that is those comprised of sub-systems and equipment referenced within the Rules. The System Operational Concept is to demonstrate that the systems' architecture, configuration and criticality meet the requirements of the operational scenarios defined by the ConOps. The System Operational Concept statements are to be agreed between the designer and the Owner. LR may accept alternative documents where these provide the information which would be included within the System Operational Concept. In such cases the relevant sections providing the information required to provide equivalence with the System Operational Concept are to be identified.

2.2.18 **System Design Description.** The System Design Description is a document that describes the design of a system or equipment. The System Design Description details the system's capability and functionality under all normal and reasonably foreseeable abnormal operating and fault conditions. The System Design Description documents are to be agreed between the designer and the Owner. LR may accept alternative documents where these provide the information which would be included within the System Design Description. In such cases the relevant sections providing the information required to provide equivalence with the System Design Description are to be identified.

2.2.19 **Engineering and Safety Justification.** A statement or report which provides a reasoned and compelling argument supported by a suitable body of evidence, that either the system or sub-system under consideration will operate as intended for a defined application in a defined environment or in the case of a deviation from the Rules, evidence that the proposed alternative arrangements are equivalent. This is to include details of the safety implications and protective measures to be implemented to mitigate risks associated with the system or alternative arrangements. It may include references to design standards used, assumptions and technical evidence such as analysis or test reports. Where required this is to be derived from a Risk Based Analysis in accordance with *Vol 1, Pt 1, Ch 2 Classification Regulations*. It may include:

(a) Possible failure modes of internal components and measures adopted to mitigate such failures that may have an effect on the internal machinery or the surrounding environment/structures/systems, taking due account of suitability of materials and the effects of stress raisers, etc.
(b) Operating parameters and any required limitations.
(c) Details of life-limited critical components, including their declared lives and residual lives or balance of planned life remaining, in terms of operating time or operating cycles, or where life is derived from declared acceptance criteria, and the associated maintenance strategies.
(d) Installation arrangements.
(e) Details of potential failures that could lead to hazardous or major consequences and/or degradation in systems performance that could lead to failures and which are to be notified to the Operators.
(f) Common failure modes and measures to minimise potential single points of failure such as system redundancy and environmental separation of equipment and services.
(g) Identification of failure modes of the defined integrated system.

In addition, an Engineering and Safety justification is to be provided for each deviation from the Rule requirements, such deviations are normally raised by the designer or Builder and are to be agreed with the Owner and Naval Administration. In some cases a full justification and Risk Assessment may be required. *See Requirements for Machinery and Engineering Systems of Unconventional Design*, *Vol 2, Pt 1, Ch 2 Requirements for Machinery and Engineering Systems of Unconventional Design* and Risk Assessment (RA) *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*.

■ *Section 3* Character of Classification and Class notations

3.1 General

3.1.1 This Section details the character symbols, Class notations which comprise the Class assigned to naval ships.

3.1.2 The character symbols identify whether the ship is built under LR Class and survey, the suitability for sea-going service, the provision of anchor handling equipment and the Rules used for the construction of the ship. The character symbols are described in *Vol 1, Pt 1, Ch 2, 3.3 Character symbols*.

3.1.3 The Class notations detail the particular features of the ship which are required to be especially considered in order to verify where additional care has been taken in particular aspects of the design of the ship. These Class notations are subject to an approval process in order to satisfy Classification requirements.

3.1.4 Optional notations detail particular features of the ship which may not form part of the hull approval process required for Classification. Typically they include details of military design features, machinery and safety/environmental aspects of the vessel.

3.1.5 The following are examples of character symbols, and Class notations as they would appear in the vessel's Classification record:

- ✠ **100A1 NS2 Frigate, SA1, AIR**
- ✠ **LMC, SCM, SDA, ESA1, RSA2, Ice Class 1C**
- ✠ **MD, SEA, EER.**

3.2 Tailoring – Departures from the Rules and Rule additions

3.2.1 In general, there are different levels of deviation from the Rules:

(a) Interpretations are applied where strict compliance with a Rule requirement cannot be achieved but where the proposed arrangement clearly satisfies the intent of the Rules. The decision to apply an interpretation is at LR's discretion and will be recorded in design appraisal documentation.

(b) Exceptions or concessions are non-compliances with Rule requirements where LR is satisfied that the arrangements presented are an acceptable alternative to its Rules on the basis of an Engineering and Safety Justification Report. Exceptions are normally raised by the designer or Builder and are to be agreed with the Owner and Naval Administration.

(c) Alternatives are deviations which represent a significant change to the Rule requirements. They may involve the use of an alternative standard to replace a Rule Chapter. In such cases, the (**NS**) character is to be appended to the notation, *see Vol 1, Pt 1, Ch 2, 3.3 Character symbols 3.3.5*. LR is to be satisfied that the arrangements are an acceptable technical alternative. Alternatives are normally raised by the designer or Builder and are to be agreed with the Owner and Naval Administration. A tailoring document or System Design Description is required to define the alternative proposal in advance of design appraisal.

3.2.2 Tailoring is to be agreed between LR and the Naval Administration. Where a departure from the Rules is not agreed by LR, an exemption is required from the Naval Administration. at Board level.

3.2.3 Additions may involve the use of a standard in addition to the LR Rule requirements. In such cases, the (**NS**) character is to be appended to the notation, *see Vol 1, Pt 1, Ch 2, 3.3 Character symbols 3.3.5*. Additions are normally raised by the designer or Builder and are to be agreed with the Owner and Naval Administration. A tailoring document or System Design Description is required to define the addition in advance of design appraisal.

3.2.4 An Engineering and Safety justification is to be provided for each deviation from the Rule requirements, *see Vol 1, Pt 1, Ch 2, 2.2 Definitions 2.2.18*.

3.2.5 At the design stage, departures from the Rules or additional requirements may be captured in a tailoring document developed by the designer. Tailoring is defined as the process by which specific requirements of a standard, specification or similar document are selected and used to meet the needs of a project. The tailoring document should cover subjects such as:

(a) Additional standards;
(b) Additional requirements of the Naval Administration or the Owner;
(c) Additional designer requirements;
(d) Interpretations;
(e) Exceptions/non-compliances against Rules;
(f) Exceptions/non-compliances against other defined standards or design policies;
(g) Equipment and component procurement.

The tailoring document should clearly define the paragraphs of the Rules which are modified, what alternative requirements are to be used and reference to the Engineering and Safety Justification, where appropriate. The tailoring document is to be submitted with the plans at the time of appraisal and referenced in appraisal documentation.

3.2.6 At the build and through-life stages, significant non-compliances, alternative or additional requirements will be recorded by LR as exceptions, using appropriate documentation. They will be clearly defined and referenced in the Classification Certificates and any associated registers.

3.3 Character symbols

3.3.1 All ships, when Classed, will be assigned a character of Classification comprising one or more character symbols as applicable, e.g. ✠ **100A1**.

3.3.2 A full list of character symbols for which a ship may be eligible is as follows:

✠ This distinguishing mark will be assigned, at the time of Classing, to new ships constructed under Special Survey, in compliance with the Rules, and to the satisfaction of LR.

100 This character figure will be assigned to all ships considered suitable for sea-going service

A This character letter will be assigned to all ships which have been built or accepted into Class in accordance with LR's Rules and Regulations, and which are maintained in good and efficient condition.

1 This character figure will be assigned to:

(a) Ships having on board, in good and efficient condition, anchoring and/or mooring equipment in accordance with the Rules.

(b) Ships Classed for a specific service, having on board, in good and efficient condition, anchoring and/or mooring equipment approved by the Classification Committee as suitable and sufficient for the particular service.

E This character letter will be assigned to ships on which LR has agreed that anchoring and mooring equipment need not be fitted in view of their particular service.

3.3.3 For Classification purposes either the character figure **1** or the character letter **E** is to be assigned.

3.3.4 In cases where the anchoring and/or mooring equipment is found to be seriously deficient in quality or quantity, the Class of the ship will be liable to be withheld.

3.3.5 Alternative or additional standards relating to the application of a character symbol or Class notation may be specified. Where these alternative or additional standards have been agreed by LR and the Naval Administration, a formal process for approval, construction, testing and verification throughout life has been established, this feature will be recognised by the addition of **(NS)** to a character symbol or Class notation. *See also Vol 1, Pt 1, Ch 2, 3.4 Class notations*. The alternative or additional requirements are to be clearly defined and referenced in the Classification Certificates and any required registers such as the register of lifting appliances. The following are examples of character symbols and Class notations that may recognise alternative or additional standards:

A(NS)	Ship built or accepted into Naval Class in accordance with LR's Rules and Regulations for assignment of the **A** character and additional specified requirements, *see Vol 1, Pt 1, Ch 2, 3.2 Tailoring – Departures from the Rules and Rule additions 3.2.5* and *Vol 1, Pt 1, Ch 2, 3.3 Character symbols 3.3.5*.
✠ **LMC(NS)**	Propelling and other machinery for Mobility and/or Ship Type systems (*see Vol 2, Pt 1, Ch 1, 3 Engineering system designation*), constructed, installed and tested under Special Survey in accordance with LR's Rules and Regulations for assignment of ✠ **LMC** Class notation and additional specified requirements, *see Vol 1, Pt 1, Ch 2, 3.2 Tailoring – Departures from the Rules and Rule additions 3.2.5* and *Vol 1, Pt 1, Ch 2, 3.3 Character symbols 3.3.5*.
LA(NS)	Lifting appliances designed and built in accordance with an agreed standard equivalent to LR's *Code for Lifting Appliances in a Marine Environment* (LAME) requirements of the Navy.
FIRE(NS)	Fire protection functional requirements are in accordance with LR's requirements for assignment of **FIRE** Class notation and additional specified fire safety requirements, *see Vol 1, Pt 1, Ch 2, 3.2 Tailoring – Departures from the Rules and Rule additions 3.2.5* and *Vol 1, Pt 1, Ch 2, 3.3 Character symbols 3.3.5*.

3.3.6 Proposals to apply the additional symbol **(NS)** to a character symbol or Class notation are to be made to LR with details of the standard, *see Vol 1, Pt 1, Ch 2, 3.2 Tailoring – Departures from the Rules and Rule additions 3.2.5* and *Vol 1, Pt 1, Ch 2, 3.3 Character symbols 3.3.5*, together with proposed processes for approval, construction, testing and verification throughout life.

3.4 Class notations

3.4.1 When considered necessary by LR, or when requested by an Owner and agreed by LR, a Class notation will be appended to the character of Classification assigned to the ship. The Class notation may consist of any of the following:

(a) a ship type notation, *see Vol 1, Pt 1, Ch 2, 3.5 Ship type notations*;
(b) a service area notation, *see Vol 1, Pt 1, Ch 2, 3.6 Service area notations*;
(c) a hull girder strength notation, *see Vol 1, Pt 1, Ch 2, 3.7 Hull strength notations*;
(d) military distinction notations, *see Vol 1, Pt 1, Ch 2, 3.8 Military Distinction notations*;
(e) machinery and engineering systems notations, *see Vol 1, Pt 1, Ch 2, 3.9 Machinery and Engineering Systems notations*;
(f) other notations, *see Vol 1, Pt 1, Ch 2, 3.10 Other notations*.

3.5 Ship type notations

3.5.1 The ship type notation will be recorded in the appropriate Classification record indicating the primary purpose for which the ship has been designed and constructed.

3.5.2 A list of ship type notations for which a ship may be eligible is:

NS1 This notation will be assigned to NS1 category naval ships, as defined in *Vol 1, Pt 1, Ch 2, 2.1 Applicable ship types 2.1.1*

NS2 This notation will be assigned to NS2 category naval ships, as defined in *Vol 1, Pt 1, Ch 2, 2.1 Applicable ship types 2.1.1*

NS3 This notation will be assigned to NS3 category naval ships, as defined in *Vol 1, Pt 1, Ch 2, 2.1 Applicable ship types 2.1.1*

NS(SR) This notation will be assigned to NS(SR) category naval ships, as defined in *Vol 1, Pt 1, Ch 2, 2.1 Applicable ship types 2.1.1*

NS(SSC) This notation will be assigned to NS(SSC) category naval ships, as defined in *Vol 1, Pt 1, Ch 2, 2.1 Applicable ship types 2.1.1*.

3.5.3 The ship type notation will be followed by a description which indicates the operational role for which the ship is designed and the hull form type, if of unusual form. The following are examples of the description of the ship's role:

Destroyer
Cruiser
Helicopter Carrier
Aircraft Carrier
Frigate
Corvette
Amphibious Assault Ship
Amphibious Transport Dock
Landing Craft
Landing Ship Dock
Minehunter
Minelayer
Mine-sweeper
Patrol ship
Fast Attack Craft
Fast Strike Craft
Fast Patrol Craft
Offshore Patrol Vessel.

3.5.4 The **NS(SR)** ship type notation will be followed by a description which indicates the operational role for which the ship is designed and operated. The following are examples of the description of an NS(SR) ship's role:

Replenishment Ship
Oil Supply Ship
Landing Ship Dock
Survey Ship
Stores Replenishment Ship
Transport Dock
Ro-Ro Ship
Troop Carrier
Vehicle Carrier
Landing Craft.

3.5.5 The **NS(SSC)** ship type notation will be followed by a description that indicates the operational role for which the ship is designed and operated. The following are examples of the descriptions of an **NS(SSC)** ship's role:

(Offshore or Inshore) Patrol Boat

(Offshore or Inshore) Patrol Vessel
Landing Craft
Air Cushioned Vehicle.

3.5.6 **NS(SR) and NS(SSC) Vessels**

For vessels that are using either the **NS(SR)** or **NS(SSC)** ship type notations, the following requirements are to be complied with:

(a) When naval ship classification using either the **NS(SR)** or **NS(SSC)** notation is requested, application should be made in writing.
(b) Where vessels are to be built to these notations, the requirements set out in *Vol 1, Pt 1, Ch 2, 3.5 Ship type notations 3.5.8* are to be complied with.
(c) Plans showing the features of the ship not covered, or fully covered by the Rules for Special Service Craft or Rules for Ships, as appropriate, are to be submitted. Where an appraisal is undertaken, strength and, where appropriate, stiffness aspects are to be addressed. Examples of features of the ship not covered, or fully covered by the Rules for Special Service Craft or Rules for Ships include:
   (i) Masts (*see Vol 1, Pt 6, Ch 3, 16 Masts*).
   (ii) Weapon system seats (*see Vol 1, Pt 4, Ch 2, 9 Military installation and operational loads*).
   (iii) RAS seats and landing areas (*see Vol 1, Pt 4, Ch 1, 5 Military design requirements* and *Vol 1, Pt 4, Ch 2, 9 Military installation and operational loads*).
   (iv) Aircraft landing guides (*see Vol 1, Pt 4, Ch 2, 10 Aircraft operations*).
   (v) Towing points (*see Vol 1, Pt 3, Ch 5, 7 Towing arrangements*).
   (vi) Military loads (*see Vol 1, Pt 4, Ch 2 Military Load Specification*).
   (vii) Beaching (*see Vol 1, Pt 4, Ch 2, 8 Strengthening requirements for beach landing operations*).
   (viii) Material grades (*see Vol 1, Pt 6, Ch 6 Material and Welding Requirements*).
   (ix) Watertight integrity (*see Vol 1, Pt 3, Ch 4 Closing Arrangements and Outfit*).
   (x) Strength of watertight structure (*see Vol 1, Pt 6, Ch 3 Scantling Determination*).
   (xi) Lifts, ramps and shell doors (*see Vol 1, Pt 4, Ch 3 Special Features*).
(d) Plans of systems within the scope of classification, as categorised in accordance with *Vol 2, Pt 1, Ch 1, 3.1 Categories* and not covered by the Rules for Special Service Craft or Rules for Ships, as appropriate, are to be submitted to LR for approval in accordance with the requirements of the respective requirements of these Rules. The following are examples of such systems:
   (i) Aircraft/helicopter and vehicle fuel storage and distribution systems (*see Vol 2, Pt 7, Ch 4 Aircraft/Helicopter/Vehicle Fuel Piping and Arrangements*).
   (ii) Chilled water systems (*see Vol 2, Pt 7, Ch 2 Ship Piping System*).
   (iii) High pressure sea-water systems (*see Vol 2, Pt 7, Ch 2 Ship Piping System*).
   (iv) High and low pressure compressed air systems (*see Vol 2, Pt 7, Ch 2 Ship Piping System*).
   (v) Hydraulic power actuating systems (*see Vol 2, Pt 7, Ch 2 Ship Piping System*).
   (vi) Made and fresh water systems (*see Vol 2, Pt 11, Ch 1 Made and Fresh Water Systems*).
   (vii) Heating, ventilation and cooling arrangements (*see Vol 2, Pt 11, Ch 2 Heating, Ventilation and Cooling Arrangements*).
   (viii) Replenishment at sea arrangements where a **RAS** notation is requested (*see Vol 3, Pt 1, Ch 5 Replenishment at Sea (RAS) Systems*).
(e) Confirmation regarding the items below is to be supplied.
   (i) Fire Safety arrangements are to be in accordance with a specified fire safety standard and certified accordingly. For vessels being built to the **NS(SSC)** notation, the requirements of the Rules for Special Service Craft, Pt 17, Fire Protection, Detection and Extinction, are appropriate.
   (ii) Stability is to be in accordance with a recognised stability standard which addresses both intact and damage stability criteria. Details of stability approval, including estimated position of waterline after damage, are to be provided to LR prior to any approvals of structural arrangements.
   (iii) Munitions safety is to be in accordance with the navies' own technical requirements for the safe stowage and handling of the types and quantities of munitions carried.
(f) Details of any aspects which may affect multiple systems are to be provided to LR including, but not limited to:
   (i) Shock.
   (ii) Operation at angles of trim or list greater than those assumed in the Rules for Special Service Craft.

(iii) Elevated or reduced ambient conditions either due to operational areas or close down arrangements.
(iv) Operational requirements for electromagnetic compatibility.
(v) Quality of electrical power supplies.

3.5.7 **Design and Operating Scenario Statement:**

This is required for **NS(SR) or NS(SSC)** ships and is to detail the civil and naval support functions of the ship. The statement is to include but is not limited to the following:

(a) Types and volumes of stores, equipment, fuels and ordnance to be carried on board.
(b) The number of crew and embarked personnel to be carried on board.
(c) International Conventions that will be applied to the ship; and any National Administration requirements that will be applied together with details of any exemptions that are being considered.
(d) National Administration and their involvement in approval and operation in service.
(e) Naval Ship Class notations that will be applied to the ship.
(f) The Rules used for design and construction of the hull structure and machinery systems.
(g) Proposed survey periodicity.
(h) Installed combat systems.
(i) Installed handling equipment for stores and equipment.
(j) Design survivability of the ship.
(k) Operational modes of the ship.

The statement is to be submitted at the time of submitting the Request for LR Services form and LR will advise acceptance of the contents of the statement before proceeding with detailed analysis of other plans and information required for classification purposes.

3.5.8 **NS3** vessels:

(a) For vessels being built to the **NS3** notation, the following shall apply where the vessel is also being designed and built to comply with appropriate statutory regulations for the intended service of the vessel.
(b) LR is to be contracted to issue Statements of Compliance with the nominated statutory regulation. Appropriate statutory regulations may include, but are not limited to:

    (i) *SOLAS - International Convention for the Safety of Life at Sea*.
    (ii) Code of Safety for Special Purpose Ships (SPS Code).
    (iii) UK MCA Small Commercial Vessel and Pilot Boat (SCV) Code or similar recognised regulation or National Standard.

(c) Vessels are to be certified for Intact and Damaged Stability, and Carriage of Munitions by a recognised Organisation. Other statutory requirements such as compliance with the International Convention for the Prevention of Pollution from Ships should also be issued by a recognised Organisation.
(d) Details of required certification are to be submitted to LR at the time of contracting. Form 2506 is to be used for this information.
(e) Where a vessel is so contracted, the following aspects of the *Rules and Regulations for the Classification of Naval Ships, January 2015, incorporating Notice No. 1 & 2* will be exempted for the requirements of Classification:

    All requirements for a Naval Administration to agree the contents of:

    (i) Concept of Operations Document(s).
    (ii) Design Statements.
    (iii) Other aspects as wherever referred to in the Rules are not applicable.

(f) The requirements of *Vol 1, Pt 5, Ch 4, 6.1 General 6.1.4* are to be complied with.
(g) The limits of the Operating Envelope to which the hull structure has been approved are to be displayed prominently in the wheelhouse.
(h) Where a vessel is to be classed using this approach, any exemptions are to be agreed by the Naval Administration and justified by using the approach set out in *Vol 2, Pt 1, Ch 2 Requirements for Machinery and Engineering Systems of Unconventional Design*, *Requirements for Machinery and Engineering Systems of Unconventional Design*.

3.6 Service area notations

3.6.1 All ships classed under the Rules will be assigned a service area notation **SA** followed by a number or letter, e.g. **SA1.**

3.6.2 Service area notations listed below are available. The definitive extents of the service areas are shown in *Figure 2.2.2 Sea areas* in Pt 5,Ch 2 and *Table 2.2.3 Environmental wave data for individual sea area* in Pt 5,Ch 2:

SA1 Service Area 1 covers ships having unrestricted world wide operation. **SA1** includes operation in all other service areas.

SA2 Service Area 2 is primarily intended to cover ships designed to operate in tropical and temperate regions. This service area excludes operating in sea areas for which a **SA1** notation is required.

SA3 Service Area 3 is primarily intended to cover ships designed to operate in tropical regions. This service area excludes operating in sea areas for which a **SA1** or **SA2** notation is required.

SA4 Service Area 4 covers ships designed to operate in Sheltered water, as defined in *Vol 1, Pt 1, Ch 2, 2.2 Definitions 2.2.13* This service area excludes operating in sea areas for which a **SA1**, **SA2** or **SA3** notation is required.

SAR Service Area Restricted covers ships that are designed to operate in a predetermined and contiguous area of operation.

3.6.3 More details of the service areas and extents are given in *Vol 1, Pt 5, Ch 2 Environmental Conditions*.

3.7 Hull strength notations

3.7.1 The following notations are available for naval ships with regard to global hull girder strength aspects:

ESA1 Extreme Strength Assessment. This notation will be assigned if it has been demonstrated that the extreme hull girder strength meets the requirements of a specified performance level with calculations performed using a simple elastic type analysis.

ESA2 Extreme Strength Assessment. This notation will be assigned if it has been demonstrated that the extreme hull girder strength meets the requirements of a specified performance level with calculations performed using an elasto-plastic type analysis.

RSA1 Residual Strength Assessment. This notation will be assigned if it has been demonstrated that the residual hull girder strength after the ship has sustained structural damage meets the requirements of a specified performance level with calculations performed using a simple elastic type analysis.

RSA2 Residual Strength Assessment. This notation will be assigned if it has been demonstrated that the residual hull girder strength after the ship has sustained structural damage meets the requirements of a specified performance level with calculations performed using an elasto-plastic type analysis.

RSA3 Residual Strength Assessment. This notation will be assigned if it has been demonstrated that the residual hull girder strength after the ship has sustained structural damage meets the requirements of a specified performance level with calculations performed using a 3D non-linear finite element analysis.

TLA Total Load Assessment. This notation will be assigned if the scantlings have been verified using a total load approach.

SDA Structural Design Assessment. This notation will be assigned when direct calculations in accordance with agreed procedures have been applied.

FDA Fatigue Design Assessment. This notation will be assigned when an appraisal has been made of the fatigue performance of the structure in accordance with agreed procedures.

3.8 Military Distinction notations

3.8.1 Military Distinction notations may be assigned if a particular feature relating to military loads has been incorporated in the design. The requirements for all the Military Distinction notations are given in *Vol 1, Pt 4 Military Design and Special Features*.

✠ **MD** This Military Distinction notation will be assigned when military aspects of the ship have been constructed under LR’s Special Survey and in accordance with LR’s Rules and Regulations.

$\overline{✠}$ **MD** This Military Distinction notation will be assigned when military aspects of the ship have been constructed under LR's Special Survey in accordance with plans approved by the Naval Administration in accordance with Rules and Regulations equivalent to those of LR.

MD This Military Distinction notation will be assigned when military aspects of the ship have been assessed by the Naval Administration in accordance with the Rules and Regulations equivalent to those of LR.

In particular, the following confidential notations are available, and will be known only to the Owner and LR.

EB1 External air blast notation. This confidential notation indicates that the ship is capable of meeting the structural requirements to withstand an external blast compatible with a specified performance level using the Rule loads and structural design methodology.

EB2 External air blast notation. This confidential notation indicates that the ship is capable of meeting the structural requirements to withstand an external blast compatible with a specified performance level using the Rule loads and an elasto-plastic structural design methodology.

EB3 External air blast notation. This confidential notation indicates that the ship is capable of meeting the structural requirements to withstand an external blast compatible with a specified performance level using the Rule loads and a finite element structural design methodology.

EB4 External air blast notation. This confidential notation indicates that the ship is capable of meeting the structural requirements to withstand an external blast compatible with a specified performance level using a full 3D non-linear code for the loads and/or structural design.

IB1 Internal air blast notation. This confidential notation indicates that the ship is capable of meeting the structural requirements to prevent the spread of an internal blast compatible with a specified performance level in accordance with rules requirements.

IB2 Internal air blast notation. This confidential notation indicates that the ship is capable of meeting the structural requirements to prevent the spread of an internal blast compatible with a specified performance level in accordance with rules requirements, supplemented by additional testing or analysis work.

FP1 Fragmentation protection notation. This confidential notation indicates that the ship is capable of meeting the local structural requirements to withstand a defined fragmentation threat compatible with a specified performance level using the rule structural requirements.

FP2 Fragmentation protection notation. This confidential notation indicates that the ship is capable of meeting the local structural requirements to withstand a defined fragmentation threat compatible with a specified performance level using fragmentation penetration algorithms.

SP Small arms protection. This confidential notation indicates that the ship is capable of meeting the local strengthening requirements to withstand an attack from a defined small arms threat compatible with a specified performance level.

SH Shock enhancement notation. This confidential notation indicates that the ship is capable of meeting, as a minimum, the local structural requirements to withstand an underwater shock compatible with a specified performance level. The strength calculations are performed using a simplified approach. The minimum local assessment may be enhanced by undertaking a more complex assessment. The performance level may be enhanced by undertaking assessment of detailed design, seat design/shock mounts, hull valve design/integration and global strength assessment.

WH1 Whipping assessment notation. This confidential notation is known only to the Owner and indicates that the ship is capable of meeting the global structural requirements to withstand an underwater shock compatible with a specified performance level using a simple elastic type analysis.

WH2 Whipping assessment notation. This confidential notation is known only to the Owner and indicates that the ship is capable of meeting the global structural requirements to withstand an underwater shock compatible with a specified performance level using an elasto-plastic type analysis.

WH3 Whipping assessment notation. This confidential notation is known only to the Owner and indicates that the ship is capable of meeting the global structural requirements to withstand an underwater shock compatible with a specified performance level using a 3D non-linear finite element analysis.

Table 2.3.1 Hull, Military and Other Class Notations

Mandatory Notations		Other Notations		
Ship Type	Service Area	Hull Strength	Military Distinction ✠ MD	Others
See Vol 1, Pt 1, Ch 2, 3.5 Ship type notations (Select one:)	*See Vol 1, Pt 1, Ch 2, 3.6 Service area notations* (Select one:)	*See Vol 1, Pt 1, Ch 2, 3.7 Hull strength notations*	*See Vol 1, Pt 1, Ch 2, 3.8 Military Distinction notations*	*See Vol 1, Pt 1, Ch 2, 3.10 Other notations*
NS1	**SA1** Service Area 1	**ESA1 ESA2** Extreme Strength Assessment	**IB1 IB2** Internal Air Blast	**PCWBT** Protective Coating in Water Ballast Tanks
NS2	**SA2** Service Area 2	**RSA1 RSA2 RSA3** Residual Strength Assessment	**EB1 EB2 EB3 EB4** External Air Blast	**ShipRight ACS (B)** Anti-Corrosion System in Water Ballast Tanks

NS3	**SA3** Service Area 3	**TLA** Total Load Assessment	**SH** Shock Enhancement	***IWS** In-water Survey
NSA	**SA4** Service Area 4	**SDA** Structural Design Assessment	**WH1 WH2 WH3** Whipping Assessment	**SMS** Safety Management System
Description of ship's role Examples:	**SAR** Service Area Restricted	**FDA** Fatigue Design Assessment	**FP1 FP2** Fragmentation Protection	**LAP** Lifting Appliances
Cruiser Helicopter Carrier			**SP** Small Arms Protection	**TA1 TA2 TA3 TA(S)** Towing Arrangements
Aircraft Carrier Destroyer				**SD** Special Duties
Frigate Corvette				**CM** Construction Monitoring
Amphibious Assault Ship Amphibious Transport Dock				**SEA (HSS-n)** Ship Event Analysis Hull Surveillance System
Landing Craft Minehunter Minelayer Mine-sweeper				**SEA (VDR)** Ship Event Analysis Voyage Data Recorder
Patrol Ship Survey Ship e.g. NS1 Helicopter Carrier				**SEA (VDR-n)** Ship Event Analysis Voyage Data Recorder (strain gauges)
Oil Supply Ship Landing Ship Dock				**ES** Enhanced Scantlings
Survey Ship Stores Replenishment Ship Transport Dock				**SERS** Ship Emergency Response Service
Ro-Ro Ship Troop Carrier Vehicle Carrier Air Cushioned Support				**EER** Escape, Emergency Access, Evacuation and Rescue (*see* Notes 1 & 2)
				FIRE Fire Protection (*see* Notes 1 & 2)
Military Operations **AIR** Aircraft Operations				**LSAE** Life Saving and Evacuation (*see* Notes 1 & 2)
LA Lifting Appliances				**ESC** Escape and Emergency Access(*see* Notes 1 & 2)
				SNC Safety of Navigation and Communication (*see* Note 1)

				POL Pollution Prevention **Ice Class** Navigation in Ice **LMA** Manoeuvring Assessment **CEPAC** Crew and Embarked Personnel Comfort **EP** Environmental Protection **LI** Approved Loading Instrument **HPMS** Hull Planned Maintenance Scheme **LE** Lifting Eyes **STAB** Buoyancy, Stability and Controllability Assessment
Note 1. Star Endorsement (*) may be assigned to this notation where the arrangements on board are in accordance with stated National Administration requirements. Note 2. Double Star Endorsement (**) may be assigned to this notation where the arrangements on board are in accordance with the requirements of *ANEP-77 NATO Naval Ship Code* (NSC).				

Table 2.3.2 Machinery Class Notations

Machinery Notations *See Vol 1, Pt 1, Ch 2, 3.9 Machinery and Engineering Systems notations*		
✠ **LMC** Mobility and/or Ship Type systems ✠̅ **LMC** Mobility and/or Ship Type systems [✠] **LMC** Mobility and/or Ship Type systems **LMC** Mobility and/or Ship Type systems **MCH** Mobility and/or Ship Type systems **SCM** Screwshaft Condition Monitoring **TCM** Turbine Condition Monitoring **PMR** Propulsion System Redundancy **PMR*** Propulsion System Redundancy in Separate Compartments **SMR** Steering System Redundancy **SMR*** Steering System Redundancy in Separate Compartments **PSMR** Propulsion and Steering System Redundancy **PSMR*** Propulsion and Steering System Redundancy in Separate Compartments **L** Additional character to **SMR, PMR, PSMR** and ***** notations for limited capability **ELS** Quality of electrical power supplies	**AG1** Enhanced analysis of propulsion and/or auxiliary gear elements **AG2** Enhanced three dimensional finite element analysis of propulsion and/or auxiliary gear elements **AP1** Enhanced assessment of propeller manufacturing tolerances on fast ships and craft **AP2** Enhanced assessment of propeller manufacturing tolerances having reduced noise characteristics **MPMS** Machinery Planned Maintenance Scheme **MCM** Machinery Planned Maintenance Scheme with Condition Monitoring **RCM** Machinery Planned Maintenance Scheme with Reliability Centred Maintenance **RAS(ABV)** Replenishment at Sea, Astern, Abeam and VERTREP **RAS(AB)** Replenishment at Sea, Abeam and Astern **RAS(AV)** Replenishment at Sea, Astern and VERTREP **RAS(BV)** Replenishment at Sea, Abeam and VERTREP **RAS(A)** Replenishment at Sea, Astern	**RAS(B)** Replenishment at Sea, Abeam **RAS(V)** Replenishment at Sea, VERTREP **(NT)** Additional to **RAS( )**, NATO requirements **UMS** Unattended Machinery Spaces **CCS** Centralised Control Station **ICC** Integrated Computer Control **IP** Integrated Propulsion **PRM** Provision Refrigeration Machinery

3.9 Machinery and Engineering Systems notations

3.9.1 The following class notations are associated with the machinery construction and arrangement, and may be assigned:

✠ **LMC** This notation will be assigned when the propelling and other machinery for Mobility and/ or Ship Type systems, *see Vol 2, Pt 1, Ch 1, 3 Engineering system designation*, has been constructed, installed and tested under Special Survey and in accordance with LR's Rules and Regulations.

✠̅ **LMC** This notation will be assigned when the propelling and other machinery for Mobility and/or Ship Type systems, *see Vol 2, Pt 1, Ch 1, 3 Engineering system designation*, has been constructed under the survey of a recognised authority in accordance with the Rules and Regulations equivalent to those of LR. In addition the whole of the machinery will be required to have been installed and tested under Special Survey in accordance with LR's Rules and Regulations.

[✠] **LMC** This notation will be assigned when the propelling arrangements, steering systems, pressure vessels and the electrical equipment for Mobility and/or Ship Type systems, *see Vol 2, Pt 1, Ch 1, 3 Engineering system designation*, have been constructed, installed and tested under LR's Special Survey and are in accordance with LR's Rules for Naval Ships. Other items of machinery for propulsion and electrical power generation including propulsion gearing arrangements and other auxiliary machinery for Mobility and/or Ship Type systems that are in compliance with LR Rules

and supplied with the manufacturer's certificate will be acceptable under this notation. The system arrangements of propelling and auxiliary machinery are required to be appraised by LR, and found to be acceptable to LR. *See Vol 1, Pt 1, Ch 2, 6.3 Survey and inspection 6.3.3*.

LMC This notation (without ✠) will be assigned when the propelling and other machinery for Mobility and/or Ship Type systems, *see Vol 2, Pt 1, Ch 1, 3 Engineering system designation*, has neither been constructed nor installed under Special Survey, but the existing machinery, its installation and arrangement has been tested and found acceptable. This notation is assigned to existing ships in service which are accepted or transferred into LR class.

MCH This notation will be assigned when the propelling and other machinery for Mobility and/or Ship Type systems, *see Vol 2, Pt 1, Ch 1, 3 Engineering system designation*, has been installed and tested under LR's survey requirements and found to be acceptable to LR. Items of machinery and equipment for propelling and auxiliary machinery for Mobility and/or Ship Type systems supplied with the manufacturer's certificate will be acceptable under this class notation. The system arrangements of propelling and essential auxiliary machinery are required to be appraised by LR, and found to be acceptable to LR. *See Vol 1, Pt 1, Ch 2, 6.3 Survey and inspection 6.3.4*.

SCM Screwshaft Condition Monitoring. The notation will be assigned where an Owner adopts the requirements for monitoring of the screwshaft. The notation will indicate that physical and operational condition of that equipment. *See Vol 1, Pt 1, Ch 3, 13.3 Screwshaft Condition Monitoring (SCM)*.

TCM Turbine Condition Monitoring. This notation will be assigned when the main propulsion steam turbines are provided with approved vibration monitoring equipment and the requirements of *Vol 1, Pt 1, Ch 3, 8.2 Turbine condition monitoring (TCM)* are complied with.

PMR This notation will be assigned where the main propulsion systems are arranged such that, in the event of a single failure in equipment, the ship will retain not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems. It also denotes that the installation has been arranged, installed and tested in accordance with LR Rules.

PMR* This notation will be assigned where the main propulsion systems are arranged such that, in the event of a single failure in equipment, the ship will retain not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems and where the machinery is installed in separate compartments such that, in the event of the loss of one compartment, the ship will retain availability of propulsion power. It also denotes that the installation has been arranged, installed and tested in accordance with LR Rules.

SMR This notation will be assigned where the steering systems for manoeuvring are arranged so that steering capability will continue to be available in the event of a single failure in the steering gear equipment or loss of power supply or control system for any steering system. It also denotes that the installation has been arranged, installed and tested in accordance with LR Rules.

SMR* This notation will be assigned where the steering systems for manoeuvring are arranged so that steering capability will continue to be available in the event of a single failure in the steering gear equipment or loss of power supply or control system for any steering system and where the steering systems are installed in separate compartments such that, in the event of the loss of one compartment, steering capability will continue to be available. It also denotes that the installation has been arranged, installed and tested in accordance with LR Rules.

PSMR This notation will be assigned where the main propulsion and steering systems are configured such that, in the event of a single failure in equipment, the ship will retain not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems and retain steering capability. It also denotes that the installation has been arranged, installed and tested in accordance with LR Rules.

PSMR* This notation will be assigned where the main propulsion and steering systems are configured such that, in the event of a single failure in equipment, the ship will retain not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems and retain steering capability. The propulsion and steering arrangements are to be installed in separate compartments such that in the event of the loss of one compartment, the ship will retain availability of propulsion power and manoeuvring capability. It also denotes that the installation has been arranged, installed and tested in accordance with LR Rules.

L This character will be added to the **PMR, SMR, PSMR** and ***** notations to indicate a limited capability.

ELS This notation will be assigned where both the quality and integrity of onboard electrical power supplies for designated loads meet the requirements of a relevant and acceptable Naval Standard, such as NATO Standardization Agreement (STANAG) 1008. It also denotes that the installation has been arranged, installed and tested in accordance with LR Rules.

AG1 This notation will be assigned where the design of gearing for propulsion and/or auxiliary purposes has used enhanced analysis methods to provide detailed knowledge of the reliability of the gear elements and where noise excitation is required to be minimised for anticipated service conditions.

AG2 This notation will be assigned where the design of gearing for propulsion and/or auxiliary purposes has in addition to the requirements for AG1, used three dimensional finite element analysis for determining the flexibility of the geometry of the mating gears.

AP1 This notation will be assigned to fast ships and craft where the propellers require an enhanced assessment of the manufacturing tolerances to control cavitation and noise characteristics.

AP2 This notation will be assigned where ships have propellers that are required to have reduced noise characteristics and have had an enhanced assessment of the manufacturing tolerances.

MPMS This notation will be assigned where the machinery installation has an approved planned maintenance scheme that incorporates preventive maintenance procedures and the requirements of *Vol 1, Pt 1, Ch 3, 15 Machinery planned maintenance and condition monitoring, MPMS, MCM and RCM* are complied with.

MCM This notation will be assigned where an approved planned maintenance scheme for machinery incorporates condition monitoring techniques that are acceptable to LR and the requirements of *Vol 1, Pt 1, Ch 3, 15 Machinery planned maintenance and condition monitoring, MPMS, MCM and RCM* are complied with.

RCM This notation will be assigned where an approved planned maintenance scheme for machinery incorporates a reliability centred maintenance analysis that is acceptable to LR and the requirements of *Vol 1, Pt 1, Ch 3, 15 Machinery planned maintenance and condition monitoring, MPMS, MCM and RCM* are complied with.

RAS(ABV) This notation will be assigned where a vessel has replenishment at sea systems that enable operations astern, abeam and VERTREP. It also denotes that the installation and arrangements are in accordance with LR Rules.

RAS(AB) This notation will be assigned where a vessel has replenishment at sea systems that enable operations abeam and astern only. It also denotes that the installation and arrangements are in accordance with LR Rules.

RAS(AV) This notation will be assigned where a vessel has replenishment at sea systems that enable operations astern and VERTREP. It also denotes that the installation and arrangements are in accordance with LR Rules.

RAS(BV) This notation will be assigned where a vessel has replenishment at sea systems that enable operations abeam and VERTREP. It also denotes that the installation and arrangements are in accordance with LR Rules.

RAS(A) This notation will be assigned where a vessel has replenishment at sea systems that enable operations astern only. It also denotes that the installation and arrangements are in accordance with LR Rules.

RAS(V) This notation will be assigned where a vessel has replenishment at sea systems that enable operations VERTREP only. It also denotes that the installation and arrangements are in accordance with LR Rules.

RAS(B) This notation will be assigned where a vessel has replenishment at sea systems that enable operations abeam only. It also denotes that the arrangements are in accordance with LR Rules.

(NT) This notation will be assigned in addition to a **RAS( )** notation where a vessel complies with NATO replenishment at sea requirements.

PRM This notation may be assigned when the provision refrigeration machinery and systems have been arranged, installed and tested in accordance with LR's Rules.

3.9.2 The following class notations are associated with the machinery control and automation, and may be assigned

UMS This notation may be assigned when the arrangements are such that the ship can be operated with the Machinery Spaces Unattended. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR’s Rules, or is equivalent thereto.

CCS This notation may be assigned when the arrangements are such that the machinery may be operated with continuous supervision from a Centralised Control Station. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR’s Rules, or is equivalent thereto.

ICC This notation may be assigned when the arrangements are such that the control and supervision of the ship operational functions are computer based. It denotes that the control engineering equipment has been arranged, installed and tested in accordance with LR’s Rules, or is equivalent thereto.

IP This notation may be assigned to a ship classed with LR when the arrangements of the machinery are such that the propulsion equipment and all other machinery for Mobility and/or Ship Type systems, *see Vol 2, Pt 1, Ch 1, 3 Engineering system designation*, is integrated with the power unit for operation under all normal sea-going and manoeuvring conditions. The system is to be bridge controlled and the propulsion equipment is to incorporate an emergency means of propulsion in the event of failure in the prime mover. It also denotes that the machinery and control equipment have been arranged, installed and tested in accordance with LR’s Rules.

3.9.3 Machinery and Engineering Systems class notations will not be assigned to ships where the hulls are not classed or intended to be classed with LR.

3.9.4 Other class notations may be assigned where the machinery and engineering systems are in accordance with the requirements of the additional features included in *Vol 3 Additional Optional Requirements* of the Rules.

3.10 Other notations

3.10.1 **LAP.** This optional special feature Class notation will be assigned to the ship in respect of the lifting appliances fitted which are designed and built in accordance with LR's *Code for Lifting Appliances in a Marine Environment, November 2015* (LAME) or equivalent standard, but where it is not mandated by the LA notation, *see Vol 1, Pt 1, Ch 2, 1.1 Framework of Classification 1.1.12*. This notation will be assigned in association with a Register of Lifting Appliances listing the appliances covered. The Register of Lifting Appliances is the responsibility of the Owner and should include the following lifting appliances, where fitted as appropriate:

(a) Bow, side and stern doors serving as ramps and/or serve to provide watertight integrity of the ship.
(b) Vehicle ramps.
(c) Movable decks.
(d) Stores lifts and munitions lifts.
(e) Cranes.
(f) Davits.
(g) Replenishment at sea positions.
(h) Engineers lifting positions.
(i) Eye plates and securing devices.
(j) Miscellaneous lifting positions.
(k) Towed body attachments.

The notation will be retained so long as the appliances are found upon examination by LR at the prescribed surveys to be maintained in accordance with the standard.

3.10.2 **LI Loading Instrument.** This notation will be assigned where an approved loading instrument has been installed either as a Class or Owner's requirement.

3.10.3 **CM Construction Monitoring** complements the **SDA** and **FDA** notations and will be assigned when the controls in construction tolerances have been applied and verified.

3.10.4 **SEA(HSS-n), SEA(VDR), SEA(VDR-n) Ship Event Analysis**. At the Owner's request, and in order to enhance safety and awareness on board during ship operation, provisions can be made for a hull surveillance system that monitors the hull girder stresses and motions of the ship and warns the ship's personnel that these levels or the frequency and magnitude of slamming motions are approaching a level where corrective action is advisable. The extension -n signifies the number of fitted strain gauges if connected to the system. The following option extensions will be added to the notation:

L The display and recording of the relevant strength information.

M The display and recording of the ship's motion.

N The facility to display and record navigational information.

VDR An interface with the ship's voyage data recorder system to enable the recording of hull stress, ship motion and hull pressure information.

3.10.5 **ES Enhanced Scantlings.** Available where scantlings in excess of the approved Rule minimum requirements are fitted at defined locations. For example, the note ES+1 will indicate that an extra 1 mm has been fitted to the hull envelope plating (i.e. deck, side and bottom).

3.10.6 **SERS Ship Emergency Response Service.** This service, offered by LR, provides a rapid computer assisted analysis of a damaged ship's stability and damaged longitudinal strength in the event of a casualty to the ship. Where an Owner adopts this service, the notation **SERS**, 'Ship is registered with LR's Ship Emergency Response Service' is available.

3.10.7 **EER Escape, Emergency Access, Evacuation and Rescue.** This notation will be assigned to naval ships which demonstrate compliance with all the requirements for **FIRE**, **ESC** and **LSAE** notations. It also denotes that the systems and their arrangements have been integrated in such a manner so as to support safe and effective task performance.

3.10.8 **FIRE Fire Protection**. This notation will be assigned to naval ships which are shown to have levels of fire protection that incorporate the functional requirements and objectives of the applicable IMO International Conventions or *ANEP-77 NATO Naval Ship Code* (NSC) and that have been accepted by LR in accordance with LR's Rules.

3.10.9 **ESC Escape and Emergency Access**. This notation will be assigned to naval ships which demonstrate levels of personnel safety in the event of a 'prepare to evacuate' situation and emergency access arrangements that incorporate the functional requirements and objectives of the applicable IMO International Conventions or *ANEP-77 NATO Naval Ship Code* (NSC) and that have been accepted by LR in accordance with LR's Rules. Where the requirements of the NSC are to be applied for an **ESC**** notation, the **LSAE**** notation must also be applied.

3.10.10 **LSAE Life-saving and Evacuation Arrangements**. This notation will be assigned to naval ships which demonstrate the provision of life-saving and rescue equipment on board that incorporates the functional requirements and objectives of the applicable IMO International Conventions *ANEP-77 NATO Naval Ship Code* (NSC) and that have been accepted by LR in accordance with LR's Rules. Where the requirements of the NSC are to be applied for an **LSAE**** notation, the **ESC**** notation must also be applied.

3.10.11 **SNC Safety of Navigation and Communication**. This notation will be assigned to naval ships which demonstrate levels of safety of navigation and communication arrangements on board that incorporate the functional requirements and objective of the applicable IMO International Conventions and that have been accepted by LR in accordance with LR's Rules.

3.10.12 **POL Pollution Prevention.** This notation will be assigned to naval ships which demonstrate that the pollution prevention arrangements on board that incorporate the functional requirements and objectives of the applicable IMO International Conventions and that have been accepted by LR in accordance with LR's Rules. The notation provides Naval Administrations with a voluntary independent assessment of their ships' compliance with IMO's environmental conventions.

3.10.13 **Ice Class notation.** An appropriate class notation for navigation in ice may be assigned when the hull structural and machinery installation are such that the ship may be operated in defined ice conditions, see below. The notation denotes that the hull structural arrangements and machinery installation have been designed, constructed, installed and tested in accordance with LR Rules or its equivalent thereto. The Class notations available are described below:

(a) **Ice Class 1AS.** This strengthening is for ships intended to navigate in first year ice conditions equivalent to unbroken level ice with a thickness of 1,0 m.

(b) **Ice Class 1A.** This strengthening is for ships intended to navigate in first year ice conditions equivalent to unbroken level ice with a thickness of 0,8 m.

(c) **Ice Class 1B.** This strengthening is for ships intended to navigate in first year ice conditions equivalent to unbroken level ice with a thickness of 0,6 m.

(d) **Ice Class 1C.** This strengthening is for ships intended to navigate in first year ice conditions equivalent to unbroken level ice with a thickness of 0,4 m.

If operation in first year is defined by the operational requirement as an emergency feature then special consideration will be given to the use of fully plastic design criteria for the shell plating. In such cases the ice class notation will be annotated with *.

3.10.14 **LMA.** This notation will be assigned where the ship's manoeuvring capability has been assessed in conjunction with engine and propulsion performance. It denotes that the manoeuvring performance has been verified through trials in accordance with LR's Rules.

3.10.15 **CEPAC.** This notation will be assigned where the noise and vibration levels in crew and embarked personnel spaces have been assessed and meet acceptance criteria for comfort. It denotes that the noise and vibration levels have been measured and reported in accordance with LR's Rules. Numerals **1** or **2** following the **CEPAC** notation indicate the acceptance criteria to which the noise and vibration levels have been assessed.

3.10.16 **ENV**. This notation will be assigned where the environmental protection arrangements demonstrate compliance with one or more characters as described in the Rules. Available characters include:

A	Anti-fouling coatings;
BWT	Ballast water treatment;
GW	Grey water and sewage;
IHM	Inventory of hazardous materials (ship recycling);
NOx-1, **NOx-2**, **NOx-3**	Emissions of nitrogen oxides;
OW	Oily water management;
P	Oil tanks in protected locations;

RS	Refrigeration Systems;
SOx	Emissions of sulphur oxides.

3.10.17 **HPMS.** This notation will be assigned where the hull structure has an approved planned maintenance scheme that incorporates maintenance and inspections by authorised ship's staff and the requirements of *Vol 1, Pt 1, Ch 3, 14 Hull planned maintenance – HPMS* are complied with.

3.10.18 **SD Special Duties Notation.** A special duties notation will be recorded in the vessel's Classification record indicating that the ship has been designed, modified or arranged for special duties other than those implied by the type notation. Ships with special duties notations are not thereby prevented from performing any other duties for which they may be suitable.

3.10.19 **PCWBT Protective Coating in Water Ballast Tanks**. This notation will be assigned to indicate that the ship's water ballast tanks are coated and that the coating remains efficient and well maintained.

3.10.20 **ShipRight ACS (B).**This notation will be assigned to Naval vessels, at the Owner's request, when protective coating systems have been applied to water ballast tanks during construction in accordance with the *ShipRight Anti-Corrosion Notations for Naval Ships procedure*.

3.10.21 ***IWS**. This notation (In-water Survey) may be assigned to a ship where the applicable LR requirements are complied with, *see Vol 1, Pt 1, Ch 2, 7 Classification of ship with *IWS notation* and *Vol 1, Pt 1, Ch 3, 4.3 In-water Surveys*.

3.10.22 Where it can be demonstrated that the vessel meets all of the buoyancy, stability and controllability performance requirements of the latest edition of Chapter III of the *ANEP-77 NATO Naval Ship Code* (NSC), a ship will be eligible to be assigned the **STAB** notation.

3.10.23 **LE**. This notation will be assigned where the lifting eyes, with a permissible loading of 2,5 tonnes or less, installed for the purpose of shipping and unshipping equipment and machinery, and which do not form part of a lifting appliance, are of an approved design, tested during construction and inspected through life in compliance with the requirements of *Vol 1, Pt 3, Ch 4, 11 Lifting eyes*.

3.10.24 **SMS** (Safety Management System). This notation will be assigned to a Naval Vessel where the safety management and operational procedures have been implemented, assessed and accepted by LR. The safety management and operational procedures are to incorporate objectives and requirements of the *International Safety Management Code* (ISM Code). This notation provides support in demonstrating that a Naval Vessel has a functioning Safety Management System in place, as required by the *ANEP-77 NATO Naval Ship Code* (NSC) and equivalent standards.

■ *Section 4*
Surveys – General

4.1 New construction

4.1.1 When it is intended to build a ship for Classification with LR, constructional plans and all particulars relevant to the hull, equipment and machinery, as detailed in the Rules, are to be submitted for the approval of LR before the work is commenced. Critical Areas *(see Vol 1, Pt 1, Ch 3, 1.5 Definitions 1.5.4*) will be identified at this stage. Any additional plans submitted will not be subject to appraisal or approval without separate agreement. Proposals for any subsequent modifications or additions to the scantlings, arrangements or equipment shown on the approved plans are also to be submitted in writing and on plans for approval.

4.1.2 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the vessel's Classification record.

4.1.3 The materials used in the construction of hulls and machinery intended for Classification are to be of good quality and free from defects and are to comply with the requirements of the Rules. Material is to be manufactured at a works approved by LR. Alternatively, tests to the satisfaction of LR will be required to demonstrate the suitability of the material.

4.1.4 Copies of the latest approved plans, essential certificates and records, required loading and other instruction manuals are to be readily available for use when required by the attending Surveyors and are thereafter required to be kept on board.

4.1.5 Where requested, LR will check the intact and damage stability calculations and approve the Stability information in accordance with the agreed standard(s).

4.1.6 **Fire Protection – FIRE.** The arrangements for fire protection, detection and extinction are to be examined to ensure that the following fire protection objectives have been satisfied:

(a) **Fire Prevention Objective**. The ship is to be designed and equipped so as to reduce the risk of the occurrence of fire or explosion, taking due account of its civil and military operational role.
(b) **Fire Detection Objective**. The ship is to be designed and equipped, as far as is practicable, to detect any potentially hazardous fire or explosion.
(c) **Fire Extinguishing Objective**. The ship is to be equipped, so far as is practicable, so that all detected fires can be safely and effectively extinguished.
(d) **Containment Objective**. The ship is to be arranged, so far as is practicable, to limit the spread of fire, smoke and toxic by-products to the space of origin.
(e) **Personnel Hazard Objective**. All reasonable measures are to be taken to prevent hazards to personnel as a result of fire.
(f) **System Interaction Objective**. The possibility of fire protection measures or systems causing fire related, or non-fire related hazards is to be kept to a level that is as low as is reasonably practicable.
(g) **Command and Control Objective**. Suitable means are to be provided to ensure any active fire control measures can be safely and effectively orchestrated.
(h) **Structural Integrity Objective**. Sufficient structural integrity is to be maintained following a fire so as to prevent the whole or partial collapse of the ship's structures due to strength deterioration by heat.

4.1.7 **Pollution Prevention – POL (Optional)**

The arrangements for prevention of pollution of the sea and air from the ship are to be examined to ensure that the following *MARPOL - International Convention for the Prevention of Pollution from Ships* Regulations have been complied with:

(a) MARPOL *Annex I of MARPOL 73/78Regulations for the Prevention of Pollution by Oil* (Prevention of Pollution by Oil)
(b) MARPOL *Annex V of MARPOL 73/78Regulations for the Prevention of Pollution by Garbage from Ships* (Prevention of Pollution by Garbage)
(c) MARPOL *Annex IV of MARPOL 73/78Regulations for the Prevention of Pollution by Sewage from Ships* (Prevention of Pollution by Sewage)
(d) MARPOL *Annex VI - Regulations for the Prevention of Air Pollution from Ships* (Prevention of Air Pollution)

4.1.8 **Life-Saving and Evacuation – LSAE**

The arrangements for life-saving and evacuation are to be examined to ensure that the following life-saving and evacuation objectives have been satisfied:

(a) **Evacuation Objective**. Arrangements are to be provided to enable personnel to evacuate the ship safely and in a time acceptable to the Naval Administration.
(b) **Personnel Protection Objective**. Evacuated personnel are to be kept protected until such time as they can be rescued from the survival craft.
(c) **Rescue Objective**. The ship is to be suitably equipped to rescue personnel from the water.
(d) **Command and Control Objective**. The ship is to be equipped and manned so that command of all evacuation and life-saving situations can be maintained.

4.1.9 **Escape and Emergency Access – ESC**

The arrangements for escape and emergency access are to be examined to ensure the following escape of personnel and emergency access objectives have been satisfied:

(a) **Escape of Personnel Objective**. The ship is to be arranged so that all spaces have means of safe and effective escape for personnel to a designated place of safety, during reasonably forseeable emergency situations.
(b) **Emergency Access Objective**. The ship is to be arranged so that personnel can access all areas with necessary equipment, for damage control and fire-fighting purposes and exercises.

4.1.10 **Safety of Navigation and Communications – SNC**

The arrangements for the safety of navigation and communications are to be examined to ensure the following safety of navigation and communication objectives have been satisfied:

(a) **Communication Objective**. The ship is to be capable of communication to avert unnecessary danger to itself and other ships in the vicinity during normal and emergency conditions.

(b) **Safety of Navigation Objective**. The ship is to be arranged with the necessary equipment to facilitate safe and effective navigation.

(c) **Equipment Arrangements Objective.** All navigation and communications equipment is to be arranged to allow safe and effective task performance.

4.1.11 **Escape, Emergency Access, Evacuation and Rescue – ERR** The arrangements for the integration of the requirements for compliance with the **FIRE**, **ESC** and **LSAE** notations are to be examined to ensure that the arrangements support safe and effective task performance.

4.2 Survey

4.2.1 The Surveyor is to be satisfied that the capability, organisation and facilities of the Builder are such that acceptable standards can be obtained for the construction of the ship and machinery.

4.2.2 In addition to *Vol 1, Pt 1, Ch 2, 4.1 New construction 4.1.3*, the hull construction of ships is to be controlled by a documented quality control system covering the Builder's management, organisation and relevant construction processes and inspection procedures.

4.2.3 New ships intended for Classification are to be built under Naval Class Special Survey. The Surveyors are to be satisfied that the materials, workmanship and arrangements are in accordance with the Rules. Any items found not to be in accordance with the Rules or the approved plans, or any material, workmanship or arrangements found so to be, are to be rectified or concession sought from LR.

4.2.4 For compliance with *Vol 1, Pt 1, Ch 2, 4.2 Survey 4.2.3*, LR will consider methods of survey and inspection for hull construction which formally include procedures involving the shipyard management, organisation and quality systems.

4.2.5 The Surveyor will prepare a report C11(N) record of hull and superstructure watertight, weathertight arrangements and closing appliances.

4.2.6 The date of completion of the Special Survey during construction of ships built under LR's supervision will normally be taken as the date of build to be entered in the *Register Book*. If the period between launching and commissioning is, for any reason, unduly prolonged, the dates of launching and completion or commissioning may be separately indicated in the *Register Book*.

4.2.7 When a ship, upon completion, is not immediately commissioned but is laid-up for a period, LR, upon application by the Owner, prior to the ship proceeding to sea, will direct an examination to be made by the Surveyors which may include a survey in dry dock. If, as the result of such survey, the hull and machinery are reported in all respects in accordance with applicable Rule requirements, the subsequent Special Survey will date from the time of such examination.

4.3 Existing ships

4.3.1 **Classification of ships not built under LR survey.** The requirements of LR for the Classification of ships which have not been built under LR's Survey are indicated in *Vol 1, Pt 1, Ch 3, 16 Classification of ships not built under LR survey*. Special consideration will be given to ships that have been designed, constructed and maintained to specified standards, and to ships transferring Class to LR from another recognised Classification Society who have appropriate Naval Ship Rules.

4.3.2 **Classification of ships built under survey to Classification Rules and Regulations other than LR Naval Ship Rules and Regulations.** The requirements of LR for the Classification of ships and craft which have not been built under LR's Survey to the LR Rules and Regulations for the Classification of Naval Ships are indicated in *Vol 1, Pt 1, Ch 3, 17 Classification of ships built under survey to LR Classification Rules and Regulations other than LR Naval Ship Rules and Regulations*

4.3.3 **Reclassification.** When reclassification or Class reinstatement is requested for a ship for which the Class previously assigned by LR has been withdrawn or suspended, LR will direct that a survey, appropriate to the age of the ship and the circumstances of the case, be carried out by Surveyors. If, at such survey, the ship is found or placed in a good and efficient condition in accordance with the Rules and Regulations, LR will be prepared to consider reinstatement of the original Class or the assignment of such other Class as may be deemed appropriate. The date of any reclassification will be recorded in the vessel's Classification record. When the original classification was not to the Rules for Naval Ships, then it will be necessary to demonstrate compliance with the additional requirements of these Rules.

4.3.4 LR reserves the right to decline an application for Classification or reclassification where the prior history or condition of the ship indicates this to be appropriate.

4.4 Damages, repairs and alterations

4.4.1 All repairs to hull, equipment and machinery which may be required in order that a ship may retain Class, *see Vol 1, Pt 1, Ch 2, 1.1 Framework of Classification 1.1.7*, are to be carried out to the satisfaction of the Surveyors. When repairs are effected at a port, terminal or location where the services of a Surveyor to LR are not available, the repairs are to be surveyed by one of the Surveyors at the earliest opportunity thereafter.

4.4.2 Any damage in association with wastage over the allowable limit (including buckling, grooving, detachment or fracture), or extensive areas of wastage over the allowable limits, which affects or, in the opinion of the Surveyor, will affect the ship's structural, watertight or weathertight integrity, is to be promptly and thoroughly repaired. Areas to be considered include, (where fitted):

- side shell frames, their end attachments or adjacent shell plating;
- deck structure and deck plating;
- bottom structure and bottom plating;
- side structure and side plating;
- inner bottom structure and inner bottom plating;
- inner side structure and inner side plating;
- watertight or oiltight bulkheads;
- hatch covers or hatch coamings.

For locations where adequate repair facilities are not available, consideration may be given to allow the ship to proceed directly to a repair facility. This may require discharging stores/equipment and/or temporary repairs for the intended voyage.

4.4.3 Where repairs are to be carried out by a riding crew during a voyage, then these must be planned in advance. A complete repair procedure, including the extent of the proposed repair and the need for a Surveyor's attendance during the voyage, is to be submitted reasonably in advance to the Surveyor for agreement. Failure to notify LR in advance of the repairs may result in the Class of the ship being specially considered by the Classification Committee. Where emergency repairs are effected immediately due to an extreme emergency circumstance, the repairs should be documented in the ship's log and submitted thereafter to LR for use in determining further survey requirements.

4.4.4 When at any survey the Surveyor considers repairs to be immediately necessary, either as a result of damage, or wear and tear, they are to communicate their recommendations at once to the Owner, or his representative. When such recommendations are not complied with, immediate notification is to be given to the vessel's Naval Classification Liaison Office by the Surveyor.

4.4.5 When at any survey it is found that any damage, defect, or breakdown (*see Vol 1, Pt 1, Ch 2, 1.1 Framework of Classification 1.1.7*) is of such a nature that it does not require immediate permanent repair, but is sufficiently serious to require rectification by a prescribed date in order to maintain Class, a suitable Condition of Class is to be imposed by the Surveyors and recommended for consideration. This condition may be designated as an operational defect, under the Owner's control, but LR needs to be kept advised as to proposed actions. The technical impact of any deficiency on the operational needs of the ship must be considered by the Surveyor in liaison with the Owner before a decision is made with regard to corrective action.

4.4.6 If a ship which is Classed with LR is to leave harbour limits or protected waters under tow, the Owner is to advise LR of the circumstances prior to her departure.

4.4.7 If a ship which is Classed with LR is taken in tow whilst at sea, the Owner is to advise LR of the circumstances at the first practicable opportunity.

4.4.8 Plans and particulars of any proposed alterations (Mods. or A's and A's) to the approved scantlings and arrangements of the hull, machinery and engineering systems are to be submitted by the Owners or their representatives for approval by LR and such alterations are to be carried out to the satisfaction of LR's Surveyors.

4.5 Existing ships – Periodical Surveys

4.5.1 **Annual Surveys** are to be held on all ships within three months, before or after each anniversary of the completion, commissioning or Special Survey. The date of the last Annual Survey will be recorded in the vessel's Classification record. This survey may include optional requirements.

4.5.2 **Intermediate Surveys** are to be held on all ships instead of the third or fourth Annual Survey after completion, commissioning or Special Survey. The date of the last Intermediate Survey will be recorded in the vessel's Classification record.

4.5.3 The Owner should notify LR whenever a ship can be examined in dry dock or on a slipway. An inspection of the underwater hull and its appendages is to be carried out not less than twice every six years. The maximum period between inspections of the hull and its appendages in dock or in-water is not to exceed three and a half years. Consideration may be given at the discretion of LR to any special circumstances justifying an extension of the maximum periods between inspections. A **Docking Survey** is to be carried out concurrently with the Special Survey. The required Docking Survey is considered to coincide with the Special Survey when held within the six months prior to the due date of the Special Survey. *See Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.5*. Where the Special Survey of the hull is carried out on a Continuous Survey basis, as given in *Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.10*, the survey in dry dock may be held at any time within the six-year cycle.

4.5.4 The date of the last Docking Survey will be recorded in the vessel's Classification record.

4.5.5 Classification details and Survey requirements for **In-water Surveys** are given in *Vol 1, Pt 1, Ch 2, 7 Classification of ship with *IWS notation* and *Vol 1, Pt 1, Ch 3, 4.3 In-water Surveys* respectively. An In-water survey can be carried out in lieu of a Docking Survey for inspection of the underwater hull and appendages between the Docking Surveys that are to be carried out concurrently with the Special Survey. The date of the last In-water Survey will be recorded in the vessel's Classification record, preceded with the notation ***IWS**.

4.5.6 All ships classed with LR are also to be subjected to **Special Surveys**. These Surveys become due at six-yearly intervals, the first one six years from the date of build or date of Special Survey for Classification as recorded in the vessel's Classification record, and thereafter six years from the date recorded in the vessel's Classification record, for the previous Special Survey. Consideration can be given, at the discretion of LR, to any exceptional circumstances justifying an extension of hull Classification beyond the sixth year. If an extension is agreed the next period of hull Classification will start from the due date of the Special Survey before the extension was granted. In this context 'exceptional circumstances' means unavailability of dry-docking facilities; repair facilities; essential materials; equipment or spare parts; delays incurred by action taken to avoid severe weather conditions; or urgent operational requirements.

4.5.7 Special Surveys may be commenced at the fifth Annual Survey or anniversary, as appropriate, after completion, commissioning, or previous Special Survey, and be progressed during the succeeding year with a view to completion by the due date of the Special Survey.

4.5.8 Special Surveys which are commenced prior to their due date are not to extend over a period greater than twelve months, except with the prior approval of LR.

4.5.9 Ships which have satisfactorily passed a Special Survey will have a record entered in the vessel's Classification record indicating the date. Where the Special Survey is completed more than three months before the due date, the new record of Special Survey will be the final date of survey. In all other cases the date recorded will be the sixth anniversary.

4.5.10 At the request of an Owner, it may be agreed that the Special Survey of the hull can be carried out on a Continuous Survey basis, all compartments of the hull being opened for survey and testing, in rotation, with an interval of six years between consecutive examinations of each part. In general, approximately one sixth of the Special Survey is to be completed each year and all the requirements of the particular hull Special Survey must be completed at the end of the six-year cycle. Ships which have satisfactorily completed the cycle will have a record entered in the vessel's Classification record indicating the date of completion which will not be later than six years from the last assigned date of Complete Survey of the hull.

4.5.11 If any examination during Continuous Survey reveals defects, further parts are to opened up and examined as considered necessary by the Surveyor, and the defects are to be made good to his satisfaction.

4.5.12 Alternative arrangements for survey periodicity will be considered by LR upon request. Requests from the Owner, at build or during service, need to be supported by adequate evidence of satisfactory performance before survey periodicity can be changed. These requests could be based upon Reliability Centred Maintenance or other forms of condition monitoring.

4.5.13 Machinery is to be submitted to the surveys detailed in *Vol 1, Pt 1, Ch 3 Periodical Survey Regulations*

4.5.14 Complete Surveys of machinery become due at six-yearly intervals, the first one six years from the date of build or date of first classification as recorded in the vessel's Classification record, and thereafter six years from the date recorded in the vessel's Classification record for the previous Complete Survey. Consideration can be given at the discretion of LR to any exceptional circumstances justifying an extension of machinery class to a maximum of three months beyond the sixth year. If an extension is agreed to, the next period of machinery class will start from the due date of Complete Survey of machinery before extension was granted. Surveys which are commenced prior to their due date are not to extend over a period greater than 12 months, except with the prior approval of LR. On satisfactory completion of a survey, an appropriate record will be made in the vessel's Classification record. Where the complete survey is completed more than three months before the due date, the new date

recorded will be the final date of survey. In all other cases the date recorded will be the sixth anniversary. *See also Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.20*.

4.5.15 Upon application by an Owner, LR may agree to the extension of the survey requirements for main propulsion machinery, which, by the nature of the ship's normal service, does not attain the number of running hours recommended by the machinery manufacturer for major overhauls within the survey periods given in*Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.14*.

4.5.16 When, at the request of an Owner, it has been agreed by LR that the Complete Survey of the machinery may be carried out on a Continuous Survey basis, the various items of machinery are to be opened for survey in rotation, so far as is practicable, to ensure that the interval between consecutive examinations of each item will not exceed six years. In general, approximately one sixth of the machinery is to be examined each year. A record indicating the date of satisfactory completion of the Continuous Survey cycle will be made in the vessel's Classification record. *See also Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.20*.

4.5.17 Upon application by an Owner, LR may agree to an arrangement whereby, subject to certain conditions, some items of machinery may be examined by the qualified naval engineering personnel responsible to the Marine Engineer Officer of the ship, followed by a limited confirmatory survey and annual audit of maintenance and repairs records. Particulars of this arrangement may be obtained from the vessel's Naval Classification Liaison Office. Where an approved planned maintenance scheme is in operation the confirmatory surveys of machinery may be held at annual intervals, at which time the records will be checked and the operation of the scheme verified. Particulars of this arrangement may also be obtained from the vessel's Naval Classification Liaison Office.

4.5.18 Where condition monitoring techniques are applied, LR, upon application by the Owner, will be prepared to amend applicable Periodical Survey requirements where details of the equipment are submitted and found satisfactory. Where machinery installations are accepted for this method of survey, it will be a requirement that an Annual Survey be held, at which time monitored records will be analysed and the machinery examined under working conditions. An acceptable lubricating oil trend analysis programme may be required as part of the condition monitoring procedures.

4.5.19 Where machinery installations include a 'lifed item' (an item of machinery, component or equipment necessary for the safety and reliability of propulsion, steering or other essential auxiliary engineering system) which is subject to an overhaul and/or ultimate life limitation, i.e. a period (expressed in operating hours or cycles and/or calendar time) at which the item is to be overhauled or scrapped, the life limitations are to be observed and take precedence over the periodicity of *Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.14* and *Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.16*where the life limitation is less than the survey periodicity. Examples may include rolling bearing elements, gas turbines, turbochargers, flexible couplings and gear box elements. The manufacturer's maintenance and service instructions are to be strictly observed. Where machinery installations include a 'lifed item' details will be noted in the classification records as a Memorandum (Machinery) record.

4.5.20 Where propulsion and auxiliary machinery is maintained using an approved 'upkeep by exchange' system, the Marine Engineer Officer is to maintain records of all exchanges carried out. At the first convenient opportunity after exchange, a running test on load is to be witnessed by a LR Surveyor (this may typically be the time of annual survey). Where prime movers are maintained by an 'upkeep of exchange' system, details will be noted in the classification records as a Memorandum (Machinery) record.

4.5.21 Boiler surveys, examination of steam pipes and Screwshaft Surveys are to be carried out as stated in *Vol 1, Pt 1, Ch 3, 11 Boilers* and *Vol 1, Pt 1, Ch 3, 12 Steam pipes* of these Regulations. On satisfactory completion, appropriate records will be made in the vessel's Classification record.

4.6 Surveys for novel/complex systems, machinery and equipment

4.6.1 Where novel/complex systems, machinery and equipment have been accepted by LR and for which existing survey requirements are not considered to be suitable and sufficient, appropriate survey requirements are to be derived as part of the design approval process. In deriving these requirements LR will consider, but not be limited to, the following:

(a) Plan appraisal submissions;
(b) Risk Assessment documentation where required by the Rules;
(c) Equipment manufacturer recommendations;
(d) Relevant recognised National or International Standards.

4.7 Certificates

4.7.1 When survey reports have been received from the Surveyors and classification has been agreed by the Classification Executive, a Certificate of Classification may be issued by an authorised Surveyor. After approval by the Classification Committee, a Certificate of First Entry of Classification, signed by LR's Chairman, or the Chairman of the Sub-Committee of Naval Classification Committee, may be issued to the Builders or Owners.

4.7.2 A Certificate of Class valid indefinitely subject to endorsement for Annual and Intermediate Surveys, as appropriate, will also be issued to the Owners and a certified copy placed on board. A new certificate will be issued when no further endorsement spaces remain.

4.7.3 LR's Surveyors will issue provisional (interim) certificates, after survey, to enable a ship Classed with LR to proceed on voyage provided that it is in a satisfactory condition. Such certificates will embody the Surveyors' recommendations for continuance of Class, and are subject to confirmation by LR.

4.8 Notice of surveys

4.8.1 It is the responsibility of the Owners to ensure that all surveys necessary for the maintenance of Class are carried out at the proper time.

4.8.2 Timely notice to an Owner about forthcoming surveys is available by means of access to LR's Class Direct. The omission of such notice, however, does not absolve the Owner from their responsibility to comply with LR's survey requirements.

4.8.3 The Owner will give timely notice of the availability of ships for survey. Should a ship not be available at the due time, the agreement for postponement of the survey should be sought from LR.

4.9 Withdrawal/Suspension of Class

4.9.1 When the Class of a ship, for which the Regulations as regards surveys on the hull, equipment and machinery have been complied with, is withdrawn by LR in consequence of a request from the Owner, the notation 'Class withdrawn at Owner's request' (with date) will be assigned.

4.9.2 When the Regulations as regards surveys on the hull equipment and machinery have not been complied with and the ship is thereby not entitled to retain Class, the Class will be suspended or withdrawn after consultation with the Owner and a corresponding notation will be assigned. In order to maintain class, LR will require documentary evidence regarding the material state of the ship, its systems and equipment in terms of reports, photographs, measures or videos where the operational requirements exceed 12 months.

4.9.3 LR will consider requirements from the Owner to continue Class where operational requirements curtail surveys being held.

4.9.4 When in accordance with *Vol 1, Pt 1, Ch 2, 4.4 Damages, repairs and alterations 4.4.4* and *Vol 1, Pt 1, Ch 2, 4.4 Damages, repairs and alterations 4.4.5* a Condition of Class is imposed, this will be assigned a due date for completion and the ship's Class will be subject to a suspension procedure if the condition of Class is not dealt with, or postponed by agreement, by the due date.

4.9.5 When it is found, from the reported condition of the hull or equipment or machinery of a ship, that an Owner has failed to comply with paragraphs *Vol 1, Pt 1, Ch 2, 1.1 Framework of Classification 1.1.7*, *Vol 1, Pt 1, Ch 2, 4.4 Damages, repairs and alterations 4.4.1* or *Vol 1, Pt 1, Ch 2, 4.4 Damages, repairs and alterations 4.4.7*, the Class will be liable to be suspended or withdrawn, at the discretion of LR, and a corresponding notation assigned.

4.9.6 When any ship proceeds to sea with a design draught greater than that approved, the Class will be liable to be withdrawn or suspended for the voyage.

4.9.7 In all instances of Class withdrawal or suspension, the assigned notation, with date of application, will appear in the vessel's Classification record. In cases where Class has been suspended by LR and it becomes apparent that the Owners are no longer interested in retaining LR's Class, the notation will be amended to withdrawn status. After Class withdrawn status has been established in the vessel's Classification record for one year, it will be automatically amended to 'Classed LR until' (with date).

4.9.8 For reclassification and reinstatement of Class, *see Vol 1, Pt 1, Ch 3, 4.3 In-water Surveys 4.3.2* and *Vol 1, Pt 1, Ch 3, 4.3 In-water Surveys 4.3.3*.

4.10 Survey of ships out of commission

4.10.1 The Classification requirements for laid up vessels will be specially considered. Surveys for continuation of Class may be required at the request of the Owners and the discretion of LR.

4.11 Appeal from Surveyor's recommendation

4.11.1 If the recommendations of the Surveyors are considered in any case to be unnecessary or unreasonable, appeal may be made to LR, who may direct a Special Examination to be held.

■ *Section 5* Type Approval/Type Testing/Quality Control System

5.1 LR Type Approval

5.1.1 LR Type Approval is an impartial certification system that provides independent third-party Type Approval Certificates attesting to a product's conformity with specific standards or specifications. It is based on design review and type testing or where testing is not appropriate, a design analysis.

5.1.2 The LR Type Approval System is a process whereby a product is assessed in accordance with a specification, standard or code to check that it meets the stated requirements and through selective testing demonstrates compliance with specific performance requirements. The testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under approval. Thereafter, the producer is required to use Quality Assurance procedures and processes to ensure that each item delivered is in conformity with that which has been Type Approved.

5.1.3 The selective testing required by *Vol 1, Pt 1, Ch 2, 5.1 LR Type Approval 5.1.2* is to include environmental testing applicable to the product's installation on board a ship classed or intended to be classed with LR.

5.1.4 LR Type Approval does not remove the requirements for inspection and survey procedures required by the Rules for equipment to be installed in ships classed or intended to be classed with LR. Also, LR Type Approval does not remove the requirement for plan appraisal of a system that incorporates Type Approved equipment where required by the Rules.

5.1.5 LR Type Approval is subject to the understanding that the producer's recommendations and instructions for the product and any relevant requirements of the Rules for the Classification of Naval Ships are fulfilled.

5.1.6 The producer supplying equipment or components under Quality Control procedures and processes is to have a recognised quality management system certified by an IACS member or a Notified Body. The Quality Control procedures and processes are to address the production of the product consistent with *Vol 1, Pt 1, Ch 2, 5.3 Quality Control System*.

5.1.7 Where equipment or components have been Type Approved in accordance with specifications and procedures other than LR's, details of the product, certification and testing are to be submitted for consideration where appropriate.

5.2 Type testing

5.2.1 Type testing is an impartial process that provides independent third-party verification that an item of machinery or equipment has satisfactorily undergone a functional type test.

5.2.2 Type testing is carried out against defined performance and test standards for a defined period of time with test conditions varying between minimum and maximum declared design conditions.

5.2.3 Type testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under assessment.

5.2.4 After type testing, mechanical equipment is to be opened out and inspected for damage or excessive wear.

5.2.5 On application from the manufacturer, type tests may be waived for equipment and machinery that has been proven to be reliable in marine service and where compliance with the current applicable standards can be demonstrated. Equipment and machinery that has been previously type tested with satisfactory testing evidence and certification need not have the type tests repeated where previous testing is in compliance with the current testing standards for the equipment.

5.2.6 The acceptance of type testing certification is subject to the understanding that the manufacturer's recommendations and instructions for the product and any relevant requirements of the applicable Rules are fulfilled.

5.3 Quality Control System

5.3.1 A quality control system for the purposes of LR acceptance of materials and machinery refers to a scheme that covers the operational techniques and activities that are used to demonstrate that the quality requirements of a product is in accordance with declared standards.

5.3.2 The quality control system for a particular product extends to all parties involved in the supply chain from manufacture and testing through to delivery of the product.

5.3.3 LR acceptance of machinery and equipment manufactured under a quality control scheme is dependent on the scheme being maintained through a traceable process involving planned audits and spot inspections at the discretion of LR Surveyors. The purpose of the audits and spot inspections is to ensure that the procedures for manufacture and quality control are being maintained in a satisfactory manner.

5.3.4 The use of a quality control system does not remove the requirements for inspection processes that may be required by the Rules applicable to the equipment being supplied with a manufacturer's certificate. Also the use of the quality control system does not remove the requirement for plan appraisal of equipment or systems where required by the Rules.

■ *Section 6*
Classification of machinery with [✠]LMC or MCH notation

6.1 General

6.1.1 After delivery of machinery and equipment with the manufacturer's certificate to the shipyard, Survey at the Shipyard and Periodical Surveys are to be in accordance with the requirements for ships built or accepted into class with the ✠ **LMC** notation.

6.2 Appraisal and records

6.2.1 To facilitate survey and compilation of classification records, the same plans and information that are required for a ship being accepted into class with the ✠ **LMC** notation, are required to be submitted for the alternative notation ✠̄ **LMC** or **MCH** for appraisal and information. Plans are not required where machinery and equipment have previously been approved by LR. In these cases it is only necessary to submit details of the machinery and equipment together with details of the previous approval.

6.3 Survey and inspection

6.3.1 The manufacturer's certificate for acceptance of machinery and equipment for assignment of the [✠] **LMC** or **MCH** notation is to be in the English language and include the following information:

(a) Design and manufacturing standard(s) used.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during design, manufacture and testing, and of any software maintenance.
(d) Details of any type approval or type testing.
(e) Details of installation and testing recommendations for the machinery or equipment.

The manufacturer is to have a recognised quality management system that is acceptable to LR.

6.3.2 The installation and testing of machinery and equipment at the build or fitting-out yard that has been supplied with a manufacturer's certificate is to be in accordance with the requirements applicable to a ship having the ✠ **LMC** notation.

6.3.3 Acceptance of manufacturer's certificates for items of machinery for propulsion (including propulsion gearing with single input/output arrangements) and for electrical power generation and for other auxiliary machinery for essential services where the ✠ LMC notation is to be assigned, is subject to the following conditions:

(a) The vessel is an NS3 ship or an NSA ship of less than 500 gross tonnage or is a ship of 500 gross tonnage or greater and is not required to comply with international conventions applicable to a ship with unrestricted service.
(b) The design and manufacture standards for all machinery and associated systems are the applicable LR Rules.
(c) The machinery and equipment are manufactured under a quality control system which is in accordance with a recognised National or International Standard for such systems that is acceptable to LR.

(d) Propellers, propulsion shafting and multiple input/output gearboxes are not included within the scope of propulsion arrangements for acceptance of a manufacturer's certificate.

6.3.4 Acceptance of the manufacturer's certificate for propelling and essential auxiliary machinery, where the MCH notation is to be assigned, is subject to the following conditions:

(a) The ship is an NS3 ship or an NSA ship of less than 500 gross tonnage or is a ship of 500 gross tonnage or greater and is not required to comply with international conventions applicable to a ship with unrestricted service.
(b) The power of any engine or gas turbine is less than 2,250 kW and the cylinder bore of any diesel engine is not greater than 300 mm.
(c) The design standards for machinery and associated systems are the applicable LR Rules or other marine standards acceptable to LR.
(d) The machinery and equipment is manufactured under a recognised quality control system that is acceptable to LR.

■ *Section 7*
Classification of ship with *IWS notation

7.1 General

7.1.1 Where the ***IWS** class notation for In-water Survey is requested, application should be made to the vessel's Naval Classification Liaison in writing with evidence of the Owner's agreement.

7.1.2 Where the ***IWS** notation is to be assigned, protection of the underwater portion of the hull is to be provided by means of a suitable high resistant paint applied in accordance with the manufacturer's requirements.

7.2 Appraisal and records

7.2.1 To facilitate survey and compilation of classification records, the following plans and particulars are to be submitted to LR for appraisal and information.

(a) Details of how the rudder pintle and bush clearances are to be measured and how the security of the pintles in their sockets is to be verified with the ship afloat.
(b) Details showing how stern bush clearances are to be measured with the ship afloat.
(c) Details of high resistant paint, for information only.

7.2.2 Where the ***IWS** notation is assigned, approved plans and particulars covering the items detailed in *Vol 1, Pt 1, Ch 2, 7.2 Appraisal and records 7.2.1* are to be placed on board.

■ *Section 8*
Classification of ship with operational role: Oil Supply Ship

8.1 General

8.1.1 Where the **Oil Supply Ship** description is to be assigned, the requirements in the *Rules and Regulations for the Classification of Ships* relating to oil tankers are to be complied with.

■ *Section 9*
Classification of naval ships using alternative LR's Rules

9.1 General

9.1.1 Where it is proposed to class a naval ship with materials of construction and operating parameters not addressed within the scope of the Naval Ship Rules, then the appropriate elements of other LR Classification Rules may be used as agreed in the Tailoring Document, *see Vol 1, Pt 1, Ch 2, 3.2 Tailoring – Departures from the Rules and Rule additions 3.2.1*.

Section

■ *Section 1* **General**

1.1 Frequency of surveys

1.1.1 The requirements of this Chapter are applicable to the Periodical Surveys set out in *Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys* Except as amended at the discretion of the Committee, the periods between such surveys are as follows:

(a) Annual Surveys – as required by *Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.1*.
(b) Intermediate Surveys – as required by *Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.2*.
(c) Docking Surveys – as required by *Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.3*.
(d) In-water Surveys, *see Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.5*.
(e) Special Surveys, *see Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.6*. For alternative arrangements, *see also Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.10*, *Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.11*, *Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.12* and *Vol 1, Pt 1, Ch 2, 1.1 Framework of Classification 1.1.2*
(f) Complete Surveys of machinery of six-yearly intervals, *see Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.14*

1.1.2 When it has been agreed that the complete survey of the hull and machinery may be carried out on the Continuous Survey basis, all compartments of the hull and all items of machinery are to be opened for survey in rotation to ensure that the interval between consecutive examinations of each part will not exceed six years, *see Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.10* and *Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.11*.

1.1.3 For the frequency of surveys of machinery, boilers, steam pipes, screwshafts, tube shafts and propellers, *see* Sections *Vol 1, Pt 1, Ch 3, 7 Machinery survey – General requirements*.

1.2 Surveys for damage or alterations

1.2.1 At any time when a ship is undergoing alterations or damage repairs, any exposed parts of the structure normally difficult of access are to be specially examined, e.g. if any part of the main or auxiliary machinery, including boilers or fittings, is removed for any reason, the hull structure in way is to be carefully examined, or when cement in the bottom, permanent ballast or sheathing on decks is removed, the structure in way is to be examined before replacement.

1.2.2 This examination should normally be carried out by a Surveyor, and the Owners should give as much notice as possible to LR so that arrangements can be made for attendance. In the absence of a Surveyor, due to the unforeseen nature of the removal, the Owner is to carry out a suitable examination and report the findings to LR as soon as practicable.

1.3 Unscheduled surveys

1.3.1 In the event that LR has cause to believe that its Rules and Regulations are not being complied with, LR reserves the right to perform unscheduled surveys.

1.3.2 In the event of significant damage or defect affecting any ship, LR reserves the right to perform unscheduled surveys of the hull of other similar ships classed by LR and deemed to be vulnerable.

1.3.3 A requirement to perform an unscheduled survey will be subject to the agreement of the Owner and operational needs.

1.4 Documentation

1.4.1 The Owner may wish to retain the originals of certificates issued by LR; however, Naval ships are required to carry the following documentation on board so that the attending Surveyor is able to carry out his duties (certified copies of certificates are acceptable):

(a) Endorsable Certificate of Class.
(b) C11(N) - Record of watertight and weathertight closing arrangements.
(c) Approved Stability information and damage control plan, and the following as applicable.
(d) Lifting Appliances Certificate.
(e) Pollution record of equipment.
(f) Tonnage Certificate.
(g) Safety Equipment Certificate and associated report.
(h) Fire control plan.

1.5 Definitions

1.5.1 **Spaces** are all separate compartments within the hull and superstructure including plated masts. Integral tanks are considered to be separate spaces.

1.5.2 **Enclosed space** is any place of an enclosed nature where there is a risk of death or serious injury from hazardous substances or dangerous conditions. Examples include, but are not limited to: boilers, pressure vessels, cargo spaces (cargo holds, or cargo tanks), cargo space stairways, ballast tanks, double bottoms, double hull spaces, fuel oil tanks, lube oil tanks, sewage-tanks, pump-rooms, compressor rooms, cofferdams, void spaces, duct keels, inter-barrier spaces, engine crankcases, excavations and pits.

1.5.3 **Representative Spaces** are those which may be expected to reflect the condition of other spaces of similar type and service and with similar corrosion prevention systems. When selecting representative spaces account should be taken of the service and repair history on board and identifiable critical areas.

1.5.4 **Critical Areas** are locations which are known to be vulnerable to corrosion, buckling and/or fatigue cracking. These will be identified at the plan approval stage.

1.5.5 **Suspect Areas** are locations within the hull structure vulnerable to increased likelihood of structural deterioration and may include:

(a) For steel hulls, areas of corrosion and/or fatigue cracking.
(b) For aluminium alloy hulls, areas of fatigue cracking and areas in the vicinity of bimetallic connections.
(c) For composite hulls, areas subject to impact damage.

(d) For high speed ships, areas of the bottom structure forward prone to slamming damage.

1.5.6 For ships designed to the *Rules and Regulations for the Classification of Ships*, **Substantial Corrosion** is defined as wastage of individual plates and stiffeners in excess of 75 per cent of allowable margins, but within acceptable limits.

1.5.7 For ships designed on a net scantling basis (using for example the *Rules and Regulations for the Classification of Naval Ships*)) **Substantial Corrosion** is defined as the wastage of individual plates and stiffeners in excess of the net scantlings, less an allowance for rolling, but within corrosion limits that are applicable for the structure concerned.

1.5.8 **Excessive Corrosion** is wastage in excess of acceptable limits that are applicable for the structure concerned.

1.5.9 **Protective Coatings** for steel ships should usually be hard coatings. Other coating systems (e.g. soft coating) may be considered acceptable as alternatives provided they are applied and properly maintained in compliance with the manufacturer's specification.

1.5.10 Coating conditions for steel ships are defined as follows:

GOOD condition with only minor spot rusting affecting not more than 20 per cent of areas under consideration.

FAIR condition with local breakdown at edges of stiffeners and weld connections and/or light rusting affecting 20 per cent or more of areas under consideration.

POOR condition with general breakdown of coating affecting 20 per cent or more of areas under consideration or hard scale affecting 10 per cent or more of the area under consideration.

1.5.11 A **Deep Tank** is a tank that extends upwards from the ship's bottom or inner bottom to or higher than the lowest deck.

1.5.12 A **Ballast Tank** is a tank which is solely used for salt-water ballast. A space which is used for purposes other than salt-water ballast but may also be used for salt-water ballast will be treated as a salt-water ballast tank when substantial corrosion has been found.

1.6 Preparation for survey and means of access

1.6.1 In order to enable the attending Surveyor(s) to carry out surveys, provisions for safe access and for survey are to be agreed between the Owner and LR.

1.6.2 Means are to be provided to enable the Surveyor to examine the structure in a safe and practical way. Where the provisions of safety and required access are determined by the Surveyor not to be adequate, then the survey of the space(s) involved is not to proceed.

1.6.3 Spaces are to be made safe for access and survey and are to be sufficiently cleaned, illuminated and ventilated.

1.6.4 In preparation for survey, thickness measurements and to allow for a thorough examination, cleaning is to include removal from surfaces of all loose accumulated corrosion scale. Spaces are to be sufficiently clean and free from water, scale, dirt, oil residues, etc. to reveal corrosion, deformation, fractures, damages or other structural deterioration, as well as the condition of the protective coating. However, those areas of structure whose renewal has already been decided by the Owner need only be cleaned and descaled to the extent necessary to determine the limits of renewed areas.

1.6.5 Where soft or semi-hard coatings have been applied, safe access is to be provided for the Surveyor to verify the effectiveness of the coating and to carry out an assessment of the conditions of internal structures which may include spot removal of the coating. When safe access cannot be provided, the soft or semi-hard coating is to be removed.

1.6.6 Prior to entering an enclosed space, it is to be verified by a competent person using a calibrated multi gas meter that the atmosphere in that space is free from hazardous gas and contains sufficient oxygen.

1.6.7 Emergency equipment and personnel are to be available in case of an emergency or rescue operation.

1.6.8 Information on procedures, equipment operating instructions and safety checklists is to be available.

1.6.9 During the survey, ventilation is to be ensured and periodic testing is to be carried out as necessary to verify that the atmosphere remains safe for access.

1.6.10 For surveys, including close-up survey where applicable, in cargo spaces and ballast tanks, one or more of the following means of access, is to be provided:

(a) Permanent staging and passages through structures.
(b) Temporary staging and passages through structures.
(c) Lifts and movable platforms.
(d) Boats or rafts.

(e) Other equivalent means.

1.6.11 Survey at sea or anchorage may be undertaken when the Surveyor is fully satisfied with the necessary assistance from the personnel on board and provided the following conditions and limitations are met:

(a) Surveys of tanks by means of boats or rafts is at the sole discretion of the attending Surveyor, who is to take into account the safety arrangements provided, including weather forecasting and ship response in reasonable sea conditions. Appropriate life jackets are to be available for all participants. The boats or rafts are to have satisfactory residual buoyancy and stability even if one chamber is ruptured. A safety checklist is also to be provided. A multi-gas meter, breathing apparatus, lifeline and whistles are to be at hand during the survey. For oil supply ships an explosimeter is also to be provided.
(b) A communication system is to be arranged between the survey party in the tank and the responsible officer on deck. This system must include the personnel in charge of ballast pump handling if boats or rafts are to be used.
(c) Surveys of tanks by means of boats or rafts will only be permitted for the under deck areas of tanks when the coating of the under deck structure is in GOOD condition and there is no evidence of wastage. The only exception to this, at the discretion of the Surveyor, is where the depth of under deck web plating is 1,5 m or less. Alternatively, rafting may be used if a permanent means of access is provided in each bay to allow safe entry and exit. This means of access is to be direct from deck via a vertical ladder and a small platform fitted approximately 2 m below deck. Where these conditions are not met, then the under deck area will require to be staged for survey.

1.7 Repairs

1.7.1 Any damage in association with wastage over the allowable limit (including buckling, grooving, detachment or fracture), or extensive areas of wastage over the allowable limits, which affects or, in the opinion of the Surveyor, will affect the ship's structural, watertight or weathertight integrity, is to be promptly and thoroughly repaired. Areas to be considered include, (where fitted):

(a) Side shell frames, their end attachments or adjacent shell plating;
(b) deck structure and deck plating;
(c) bottom structure and bottom plating;
(d) side structure and side plating;
(e) inner bottom structure and inner bottom plating;
(f) inner side structure and inner side plating;
(g) watertight or oiltight bulkheads;
(h) hatch covers or hatch coamings.

For locations where adequate repair facilities are not available, consideration may be given to allow the ship to proceed directly to a repair facility. This may require discharging the cargo and/or temporary repairs for the intended voyage.

1.7.2 Additionally, when a survey results in the identification of substantial corrosion or structural defects, either of which, in the opinion of the Surveyor, will impair the ship's fitness for continued service, remedial measures are to be implemented before the ship continues in service.

1.8 Thickness measurement at surveys

1.8.1 This Section is applicable to the thickness measurement of the hull structure where required by *Vol 1, Pt 1, Ch 3, 2 Annual Surveys – Hull, machinery and optional requirements*, *Vol 1, Pt 1, Ch 3, 3 Intermediate Surveys – Hull and machinery requirements*, *Vol 1, Pt 1, Ch 3, 5 Special Survey – Hull requirements*, and *Vol 1, Pt 1, Ch 3, 6 Special Survey – Thickness measurement requirements for steel ships*.

1.8.2 Further to the requirements of *Vol 1, Pt 1, Ch 3, 1.6 Preparation for survey and means of access 1.6.11* a survey planning meeting is to be held between the attending Surveyor(s), the Owner's representative and the thickness measurement firm's representative, so as to ensure the safe and efficient execution of the surveys and thickness measurements to be carried out on board.

1.8.3 Thickness measurements are normally to be taken by means of ultrasonic test equipment and are to be carried out by a company approved in accordance with LR's *Approval for Thickness Measurement of Hull Structures*.

1.8.4 The Surveyor may require measuring the thickness of the material in any portion of the structure where signs of wastage are evident or wastage is normally found. Any parts of the structure which are found defective or excessively reduced in scantlings are to be made good by materials of the approved scantlings and quality. Attention is to be given to the structure in way of discontinuities.

1.8.5 Thickness measurements are to be witnessed by the Surveyor. This requires the Surveyor to be on board, while the measurements are carried out, to the extent necessary to control the process. This also applies to thickness measurements carried out while the ship is at sea.

1.8.6 The Surveyor may extend the scope of thickness measurement if deemed necessary.

1.8.7 Where it is required as part of the survey to carry out thickness measurements for the structural areas subject to Close-up Survey, then these measurements are to be carried out simultaneously with the Close-up Survey.

1.8.8 Thickness measurements are to be taken at the forward and aft areas of shell plates. A number of readings should be taken in a local area, and averaged to provide the recorded reading. The extent of local substantial corrosion of plates is to be established by intensive measurement in the affected areas. Where measured plates are to be renewed, the thicknesses of adjacent plates in the same strake are to be reported.

1.8.9 A report is to be prepared by the approved company carrying out the thickness measurements. The report is to give the location of measurement, the thickness measured as well as the corresponding original thickness. The report is to give the date when measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the operator.

1.8.10 The thickness measurement report is to be verified and signed by the Surveyor and countersigned by an authorising Surveyor.

1.8.11 In all cases the extent of the thickness measurements is to be sufficient to represent the actual average condition.

■ *Section 2*
Annual Surveys – Hull, machinery and optional requirements

2.1 General

2.1.1 Annual Surveys are to be held concurrently with any relevant maintenance period and in consultation with the Owner with regard to operational needs.

2.1.2 At Annual Surveys, the Surveyor is to examine the hull, so far as necessary and practicable, in order to be satisfied as to its general condition.

2.1.3 Particular attention is to be paid to critical areas.

2.2 Hull

2.2.1 The Surveyor is to be satisfied regarding:

(a) The efficient condition of doors, hatchways and lifts on upper and superstructure decks, weather deck plating and air pipes, exposed casings, deck-houses, superstructure bulkheads, side, bow and stern doors, windows, side scuttles and deadlights, guard rails, life-lines, ladders, pressure relief plates and other openings, together with all closing appliances and flame screens. In addition, the Surveyor is to externally examine all air pipe heads installed on exposed decks.
(b) The efficient operating condition of mechanically operated hatch covers including stowage, fit, securing, locking, sealing and operational testing of hydraulic power components.
(c) The efficient condition of scuppers and sanitary discharges (so far as is practicable); valves on discharge lines (so far as is practicable) and their controls; guard rails and bulwarks.

2.2.2 Any hatch covers and coamings together with any doors, lifts or ramps which form part of the watertight integrity of the hull are to be examined to ensure that no alterations have been made to the approved arrangements.

(a) Mechanically operated lifts, hatch covers or doors are to be tested for tightness to confirm the satisfactory condition of securing and sealing arrangements; drainage channels; operating mechanisms. Associated drainage channels and operating mechanisms, such as tracks and wheels, are also to be examined to confirm they are in satisfactory condition.
(b) Hatch covers of the portable type are to be examined to confirm that the covers and closing appliances are in a satisfactory condition.

This examination will include hatches and doors in superstructures.

2.2.3 The anchoring and mooring equipment is to be examined so far as is practicable.

2.2.4 The watertight doors/closures in watertight bulkheads and any indicators or alarms are to be examined and operationally tested locally and, where applicable remotely. Other watertight bulkhead penetrations are to be examined so far as is practicable.

2.2.5 The Surveyor is to be satisfied regarding the draught marks on the ship's side.

2.2.6 The Surveyor is to be satisfied that no alterations have been made to the ship which affect stability and strength.

2.2.7 The Surveyor is to be satisfied that any alterations to approved scantlings and arrangements to the structure of magazine spaces have been approved by LR, *see Vol 1, Pt 1, Ch 2, 4.4 Damages, repairs and alterations 4.4.8*.

2.2.8 The surveyor is to check the C11(N) on board the vessel and verify with the actual arrangement on board.

2.2.9 For steel ships, the requirements of *Vol 1, Pt 1, Ch 3, 3.2 Hull 3.2.2* and *Vol 1, Pt 1, Ch 3, 5.4 Examination and testing – Additional items for steel ships 5.4.2* regarding the survey of water ballast spaces, compensated fuel tanks, integral sanitary tanks and bilges are also to be complied with as applicable.

2.2.10 The Surveyor is to carry out an examination and thickness measurement of structure identified at the previous Special Survey or Intermediate Survey as having substantial corrosion.

2.2.11 The first Annual Survey should include a review of the year's service, taking into account feedback from the Owner. Special attention needs to be given to areas of the structure where defects have become apparent. It is important that this information is fed back to the Design Authority and building yards for follow-on ships.

2.3 Machinery

2.3.1 The Surveyor is to generally examine the machinery and boiler spaces with particular attention being given to the propulsion system, auxiliary machinery and to the existence of any fire and explosion hazards. Emergency escape routes are to be checked to ensure that they are adequately identified and free of obstruction.

2.3.2 The means of communication between the navigating bridge and the machinery control positions, as well as the bridge and the alternative steering position, if fitted, are to be tested.

2.3.3 The Surveyor is to examine and test in operation all main and auxiliary steering arrangements including their associated equipment and control systems.

2.3.4 The bilge pumping and dewatering systems and bilge wells, including operation of extended spindles and level alarms, where fitted, are to be examined so far as is practicable. Satisfactory operation of the bilge pumps and dewatering eductors is to be proven, including access to all bilge areas.

2.3.5 Piping systems containing fuel oil, lubricating oil or other flammable liquids are to be generally examined and operated as far as practicable, with particular attention being paid to tightness, fire precaution arrangements, flexible hoses and sounding devices.

2.3.6 The Surveyor is to be satisfied regarding the condition of non-metallic joints in piping systems which penetrate the hull, where both the penetration and the non-metallic joint are below the deepest waterline.

2.3.7 The Surveyor is to be satisfied regarding the following items associated with machinery installations.

(a) Locking arrangements for locked valves and inspection covers.
(b) Integrity of guards for rotating machinery.
(c) Lighting arrangements, particularly at control and instrumentation panels.
(d) Operation of automatic start-up of pumps and systems for essential systems where they are required by the Rules.
(e) Condition of machinery securing and mounting arrangements.
(f) The condition of bulkhead glands.

2.3.8 The boilers, other pressure vessels and their accessories and associated fittings including safety devices, foundations, controls, relieving gear, high pressure and waste steam piping, insulation and gauges, are to be generally examined. Surveyors should confirm that Periodical Surveys of pressure vessels have been carried out as required by the Rules and that the safety devices have been tested.

2.3.9 Records of boiler treatment and analyses are to be retained on board and audited annually by the LR Surveyor. The water treatment and results of analyses are to be in accordance with the manufacturer's recommendations.

2.3.10 The main propulsion, essential auxiliary and emergency generators including safety arrangements, controls and foundations are to be generally examined. Surveyors are to confirm the Periodical Surveys of engines have been carried out as required by the Rules and that safety devices have been tested.

2.3.11 The electrical equipment and cabling forming the main and emergency electrical installations are to be generally examined under operating conditions as far as is practicable. Particular checks are to be made on the integrity of electrical enclosure and cleanliness of switchboards and bus bars. The satisfactory operation of the main and emergency sources of power and electrical services essential for safety in an emergency is to be verified; where the sources of power are automatically controlled they should be tested in the automatic mode. Bonding straps for the control of static electricity and earthing arrangements are to be examined where fitted.

2.3.12 The electrical installation in areas deemed dangerous, such as magazine spaces and spaces where low flash point oils are stored and handled and compartments adjacent to such spaces, is to be examined in order to verify that it is of the correct type, is in good condition and has been properly maintained.

2.3.13 For Mobility, Ship Type and emergency machinery control engineering systems, a general examination of the equipment and arrangements is to be carried out. Records of modifications are to be made available for review by the attending Surveyor. The documentation required by *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*, including configuration management, is to be reviewed following system modifications to confirm compliance with applicable Rules. Satisfactory operation of the safety devices and control systems is to be verified. For ships having **UMS** or **CCS** notation, a general examination of the control engineering equipment required for these notations is also to be carried out.

2.3.14 For ships fitted with an electronically controlled engine for main propulsion, essential auxiliary or emergency power purposes, the following is to be carried out to the satisfaction of the Surveyor:

(a) Verification of evidence of satisfactory operation of the engine and, where possible, this is to include a running test under load.
(b) Verification of satisfactory operation of the safety devices and control, alarm and monitoring systems.
(c) Verification that any changes to the software or control, alarm, monitoring and safety systems that affect the operation of the engine have been assessed by LR and are under configuration management control.

2.3.15 Dead ship starting arrangements for bringing machinery into operation without external aid are to be tested to the Surveyor's satisfaction.

2.3.16 The Surveyor is to be satisfied that any alterations to approved equipment, piping, cabling and electrical systems in magazine spaces have been approved by LR, *see Vol 1, Pt 1, Ch 2, 4.4 Damages, repairs and alterations 4.4.8*.

2.3.17 For ships fitted with machinery shock arrangements in accordance with *Vol 2, Pt 1, Ch 3, 4.11 Machinery shock arrangements*, the following is to be carried out to the satisfaction of the Surveyor:

(a) A general examination of shock mounts including their condition, date of manufacture and deflection under static load. Particular attention is to be given to mounts which have been installed since the previous survey and to those on which the mounted machinery has been replaced.
(b) Verification that clearances for shock mount deflection and flexible connections around shock capable equipment have been maintained.

2.4 Other notations

2.4.1 Where the options described in *Vol 1, Pt 1, Ch 3, 2.4 Other notations 2.4.2*, *Vol 1, Pt 1, Ch 3, 2.4 Other notations 2.4.4* and *Vol 1, Pt 1, Ch 3, 2.4 Other notations 2.4.6* are required by the Owner, a notation will be assigned and surveys are to be included with the Annual Survey.

2.4.2 **Fire Protection (FIRE).** The arrangements for fire protection, fire detection and extinction are to be examined and are to include the following items:

(a) Verification, so far as is reasonably practicable, that no significant changes have been made to the arrangements for structural fire protection.
(b) Verification of the operation of manual and/or automatic doors where fitted.
(c) Verification that fire control plans are properly posted.
(d) Examination, so far as is possible, and testing as feasible, of the fire and/or smoke detection and alarm system(s).
(e) Examination of the water fire-fighting system, and confirmation that each pump connected to the water fire-fighting system, including any emergency fire pump can be operated separately so that the required jets of water can be produced simultaneously from different hydrants.

(f) Verification that fire-hoses, nozzles, applicators and spanners are in good working condition and situated at their respective locations.
(g) Examination of fixed fire-fighting systems, controls, piping, instructions and marking, checking for evidence of proper maintenance and servicing, including date of last systems tests, including operational alarm tests.
(h) Verification that all portable and semi-portable fire-extinguishers are in their stowed positions, checking for evidence of proper maintenance and servicing, conducting random checks for evidence of discharged containers.
(i) Verification, so far as is reasonably practicable, that the remote control for stopping fans in accommodation spaces and the means of cutting off power to the galley are in good working order.
(j) Examination of the closing arrangements of ventilators, hatches and doorways where applicable.
(k) Verification that the fireman's outfits are complete and in good condition.

2.4.3 **Escape and Emergency Access (ESC).** The arrangements for escape of personnel and emergency access are to be examined and are to include the following:

(a) Verification, so far as is reasonably practical, that no significant changes have been made to the arrangements for escape and emergency access.
(b) Verification that all normal and emergency escape and emergency access routes are free of obstruction.

2.4.4 **Life Saving and Evacuation Arrangements (LSAE).** The arrangements for life saving and evacuation are to be examined and are to include the following:

(a) Verification, so far as is reasonably practicable, that no significant changes have been made to the arrangements for life saving and evacuation.
(b) Verification of Life-jackets, Life-buoys, Immersion Suits, Thermal Protection Aids, etc. and their attachments for effectiveness and condition.
(c) That rescue boats and survival craft have been serviced by an approved servicing company, and ascertain that they are identified and certificated with a valid date.
(d) That the rescue boat and launching/recovery arrangements are in full working order.
(e) The the survival craft launch arrangements, are in a good working order.

2.4.5 **Safety of Navigation and Communication (SNC).** The arrangements for navigation and communication equipment are to be examined and are to include the following:

(a) Verification, so far as is reasonably practicable that no significant changes have been made to the navigation and communication equipment.
(b) That the ship is in possession of up-to-date Nautical Publications, Emergency Instructions, International Code of Signals, Operating Instructions for Life-saving Appliances and their maintenance.
(c) Shipboard navigational equipment.
(d) Signalling equipment (lights and sounds).
(e) Navigation lights.
(f) Rockets and signals (pyrotechnics).
(g) Black shapes.

2.4.6 **Pollution Prevention (POL)** The arrangements for pollution prevention are to be examined and are to include the following:

(a) **Oil.** Verification of piping system arrangements between tanks, bilge and ballast systems, which are used to transfer oil/oily water and ballast water to ensure that no changes have been made to the systems since they were installed. Checking oil filters, oily water separators and sludge/oily water residue containment.
(b) **Sewage.** Verification of the sewage treatment arrangements, containment and the piping systems.
(c) **Garbage.** Verification of the garbage disposal arrangements and the installation of the equipment to ensure that no unauthorised changes have been made.
(d) **Air.** Verification that the engine exhaust emissions are still within the NO_x Technical Code. Verification of the incinerator installation. Re-testing the fuel oils to ensure that the sulphur content is still below 4,5 per cent.

Section 3
Intermediate Surveys – Hull and machinery requirements

3.1 General

3.1.1 Intermediate Surveys are to be held concurrently with any relevant maintenance period wherever practicable, *see Vol 1, Pt 1, Ch 3, 2.1 General 2.1.1*

3.2 Hull

3.2.1 The requirements of *Vol 1, Pt 1, Ch 3, 2 Annual Surveys – Hull, machinery and optional requirements* are to be complied with so far as applicable.

3.2.2 For steel ships a general examination of salt water ballast tanks, compensated fuel tanks, integral sanitary tanks and bilges is to be carried out as required below. If such inspections reveal no visible structural defects then the examination may be limited to a verification that the protective coating remains in GOOD condition as defined in *Vol 1, Pt 1, Ch 3, 1.5 Definitions 1.5.9*. When considered necessary by the Surveyor thickness measurement of the structure is to be carried out. Where the protective coating is found to be other than in GOOD condition, and it has not been repaired, maintenance of Class will be subject to the spaces in question being internally examined and gauged as necessary at Annual Surveys.

(a) For all ships over six years of age and up to 12 years of age, representative salt-water ballast tanks, compensated fuel tanks, integral sanitary tanks and bilges are to be generally examined. Where the protective coating is found to be other than in GOOD condition, as defined in *Vol 1, Pt 1, Ch 3, 1.5 Definitions 1.5.9*, or other defects are found, the examination is to be extended to other spaces of the same type.
(b) For steel ships over twelve years of age all salt-water ballast tanks, compensated fuel tanks, integral sanitary tanks and bilges are to be generally examined.

3.2.3 For all ships over twelve years of age the anchors are to be partially lowered and raised using the capstan/ windlass.

3.2.4 Representative internal spaces including fore and aft peak spaces, plated masts, machinery spaces, bilges, etc. are to be generally examined. These spaces should include all suspect areas, *see Vol 1, Pt 1, Ch 3, 1.5 Definitions 1.5.5*

3.2.5 The Surveyor is to carry out a Close-up Survey and thickness measurement of the structure identified at the previous Special Survey as having substantial corrosion.

3.3 Machinery

3.3.1 Machinery and boiler spaces including tank tops, bilges and cofferdams, sea suctions and overboard discharges are to be generally examined.

3.3.2 Areas deemed dangerous, such as magazine spaces and spaces where low flash point oils are stored and handled and compartments adjacent to such spaces are to be examined for the following type:

(a) Defective and non-certified safe electrical equipment.
(b) Improperly installed, defective and dead-end wiring. An electrical insulation resistance test of the circuits terminating in, or passing through dangerous spaces is to be carried out.

3.3.3 Electrical generators are to be examined under working conditions to verify compliance with *Vol 2, Pt 10, Ch 1, 3 Performance requirements*.

Section 4
Docking Surveys and In-water Surveys

4.1 General

4.1.1 At Docking Surveys or In-water Surveys the Surveyor is to examine the ship and machinery so far as necessary and practicable, in order to be satisfied as to the general condition.

4.2 Docking Surveys

4.2.1 Where a ship is in dry dock or on a slipway it is to be placed on blocks of sufficient height, and proper staging is to be erected as may be necessary for the examination of the outside of the hull, rudder(s) and underwater fittings. The outside surface of the hull is to be cleaned as may be required by the Surveyor.

4.2.2 The external shell plating is to be examined for excessive corrosion, structural deterioration from causes such as high stresses, chafing or contact with the ground, to areas of structural discontinuity and for undue unfairness or buckling. Special attention is to be given to the connection between the bilge strakes and the bilge keels.

4.2.3 The following parts of the external hull structure are to be specially examined:

(a) For steel hulls attention is to be given to parts of the structure particularly liable to excessive corrosion and to any undue unfairness of the plating of the bottom. The coating system is to be examined and made good as necessary.
(b) For aluminium alloy hulls attention is to be given to areas adjacent to any bimetallic connections at skin fittings, etc.
(c) For composite hulls the gelcoat or other protective finish is to be examined for surface cracking, blistering, abrasion or other damage which may impair the efficiency of the protection to the underlying laminate.

4.2.4 Where fitted, the satisfactory condition, attachment and operation of the cathodic protection (active or passive) is to be confirmed.

4.2.5 The sea connections and overboard discharge valves, their attachments to the hull and the gratings at the sea inlets are to be examined. Where applicable, pressure testing of the rudder may be required if deemed necessary by the Surveyor.

4.2.6 The clearances of the rudder bearings and pintles are to be measured. Where considered necessary by the Surveyor, rudders and stabilisers are to be lifted for examination of the stock. The securing of rudder and stabiliser couplings is to be confirmed.

4.2.7 Special attention is to be given to the hull in way of underwater fittings such as thrusters, shaft brackets, stabilisers, rudders, rope guards, eddy plates, GRP domes, bilge keels, echo sounders, and their attachments.

4.2.8 Where applicable, attention is to be given to the connection and/or intersection of the cross-deck structure to the hulls of multi-hull ships.

4.2.9 When chain cables are ranged, the anchors and cables are to be examined by the Surveyor, *see also Vol 1, Pt 1, Ch 3, 5.3 Examination and testing – General 5.3.6* and *Table 3.5.1 Survey preparation*

4.2.10 For Surface Effect Ships any flexible skirts together with their attachment are to be examined.

4.2.11 For hydrofoil or foil assisted craft the attachment of foils is to be examined.

4.2.12 The Surveyor is to verify all draught markings as applicable at the time of dry-docking.

4.2.13 When Machinery Naval Class has been adopted, the following items are additionally applicable. The work is to be carried out in accordance with maintenance manuals and the manufacturer’s recommendations for servicing and renewals observed.

(a) The propeller and fastenings are to be examined. (Where a controllable pitch propeller is fitted, examination is to include blade fastenings and hub). The sternbush is to be examined as far as practicable.
(b) Where propeller shafts are wrapped for corrosion protection, the condition of the wrapping is to be confirmed.
(c) The clearance in the sternbush or the efficiency of the oil glands is to be ascertained. The clearance of any shaft bracket bearing is to be ascertained.
(d) The inboard shaft seals or glands are to be examined. Where flexible sternglands are fitted, the satisfactory condition of the rubber hose and securing clips is to be confirmed. Where inflatable shaft seals are fitted, their condition and operation are to be verified.
(e) Visible parts of side thrusters are to be examined. Other propulsion systems which also have manoeuvring characteristics (such as directional propellers, vertical axis propellers, water jet units) are to be examined externally with focus on the condition of gear housing, propeller blades, bolt locking and other fastening arrangements. Sealing arrangements of propeller blades, propeller shaft and steering column are to be verified.
(f) Where water jet units are fitted, the impeller, hull ducting, grating, nozzle steering and reversing arrangements are to be examined as far as practicable.
(g) Where podded propulsion units are fitted, the bearings and sealing arrangements, steering ring and thrust bearings in the hull are to be examined as far as practicable.

4.3 In-water Surveys

4.3.1 The Committee will accept an In-water Survey between Special Surveys, as a Docking Survey, where suitable protection is applied to the underwater portion of the hull. If requested, the ***IWS** notation may be assigned on satisfactory completion of the survey, provided that the applicable requirements of the Rules are complied with.

4.3.2 The In-water Survey is to provide the information normally obtained from the Docking Survey, *see Vol 1, Pt 1, Ch 3, 4.2 Docking Surveys 4.2.2*.

4.3.3 The underwater part of the hull should be marked with search lines for reference purposes.

4.3.4 The In-water Survey is to be carried out at an agreed geographical location under the surveillance of a Surveyor to LR, with the ship in sheltered waters and with weak tidal streams and currents. The in-water visibility is to be good and the hull below the waterline is to be clean. The Surveyor is to be satisfied that the method of pictorial presentation is satisfactory by use of CCTV. There is to be good two-way communication between the Surveyor and the diver.

4.3.5 Prior to commencing the In-water Survey, the equipment and procedures for both observing and reporting the survey are to be agreed between the Owners, the Surveyor and the diving firm.

4.3.6 The In-water Survey is to be carried out by a qualified diver employed by the firm approved by LR.

4.3.7 If the In-water Survey reveals damage or deterioration that requires early attention, the Surveyor may, in consultation with the Owner, require that the ship be dry-docked in order that a fuller survey can be undertaken and the necessary work carried out.

4.3.8 Where a vessel has the ***IWS** notation, the condition of the high resistant paint is to be confirmed at each dry docking in order that the ***IWS** notation can be maintained.

■ *Section 5*
Special Survey – Hull requirements

5.1 General

5.1.1 The survey is to be of sufficient extent to ensure that the hull and related equipment is in satisfactory condition and is fit for its intended purpose, subject to proper maintenance and operation and to Periodical Surveys being carried out as required by the Regulations.

5.1.2 The requirements of *Vol 1, Pt 1, Ch 3, 2 Annual Surveys – Hull, machinery and optional requirements* are to be complied with so far as applicable.

5.1.3 A Docking Survey in accordance with the requirements of *Vol 1, Pt 1, Ch 3, 4.2 Docking Surveys* is to be carried out as part of the Special Survey.

5.2 Preparation

5.2.1 The ship is to be prepared for survey in accordance with the requirements of *Table 3.5.1 Survey preparation* The preparation should be of sufficient extent to facilitate an examination to ascertain any excessive corrosion, erosion, deformation, fractures, damages and other structural deterioration.

5.2.2 Where, in accordance with *Table 3.5.1 Survey preparation*, the ship is opened out by removal of linings, etc. and defects are found, further opening out may be required in order that the Surveyor can confirm the full extent of the defects.

5.3 Examination and testing – General

5.3.1 All spaces within the hull and superstructure including integral tanks are to be examined, *see also Vol 1, Pt 1, Ch 3, 5.4 Examination and testing – Additional items for steel ships 5.4.1* for tank examinations on steel ships. Special attention is to be paid to any suspect areas, *see Vol 1, Pt 1, Ch 3, 1.5 Definitions 1.5.5* and *Table 3.5.1 Survey preparation*

5.3.2 Double bottom, deep, ballast, peak and other tanks assigned also for the carriage of salt-water ballast, are to be tested with a head of liquid to the top of air pipes or to the top of hatches for ballast/cargo holds. Boundaries of fuel oil, lubricating oil and fresh water tanks are to be tested with a head of liquid to the maximum filling level of the tank. Tank testing of fuel oil, lubricating oil and fresh water tanks may be specially considered based upon a satisfactory external examination of the tank boundaries, and a

confirmation from the Commanding Officer stating that the pressure testing has been carried out according to the requirements with satisfactory results.

5.3.3 Where repairs are effected to the hull or bulkheads, any integral tanks in way are to be tested to the Surveyor's satisfaction on completion of these repairs.

5.3.4 All decks, masts and superstructures are to be examined.

5.3.5 Attention is to be given to the corners of openings and other discontinuities in the hull structure.

Table 3.5.1 Survey preparation

Special Survey I (Ship 6 years old)	Special Survey II (Ship 12 years old)	Special Survey III (Ship 18 years old) and subsequent special surveys
(1) All spaces in the ship are to be cleared and cleaned as necessary, including all bilge spaces in order that the Surveyor may be satisfied as to the condition of the structure, *see Vol 1, Pt 1, Ch 3, 1.5 Definitions 1.5.4* and *Vol 1, Pt 1, Ch 3, 1.5 Definitions 1.5.5*. A record is to be made of where equipment was removed during the survey. This record is to be retained for reference during subsequent surveys.	In addition to the requirements for Special Survey I, the following are to be complied with:	In addition to the requirements for Special Survey II the following are to be complied with:
(2) Machinery compartments are to be cleared and cleaned as necessary, and the bilges cleaned and prepared for examination. Floor plates in engine spaces are to be lifted as may be necessary for the examination of the structure below. Where necessary, pipework may be required to be removed for examination of the structure.	*(1)* The chain locker is to be cleared and cleaned internally for examination of the structure and examination of the cable securing arrangements. The chain cables are to be ranged for inspection. The anchors are to be cleaned and placed in an accessible position for inspection.	*(1)* Samples of lagging and lining are to be removed in order that the Surveyor may be satisfied as to the condition of the structure.
*(3)*In ships having wood decking or sheathing, and in refrigerated stores, a sufficient amount of material covering the structure is to be removed for access and examination. The amount of removal will depend upon the condition found and will be to the Surveyor's satisfaction.	*(2)* The rudders are to be unshipped for examination of the rudder stock and trunk at the discretion of the Surveyor.	*(2)* All wood decks and sheathing, or other covering, on steel decks are to be removed in order to ascertain the condition of the structure.
*(4)*Tanks are to be cleaned as necessary in order to satisfy the requirements of *Table 3.5.2 Tank internal examination requirements for steel ships*.		
Note 1. These requirements can be amended to reflect proven information concerning the performance of structure through an Owner's maintenance system such as 'Reliability Centred Maintenance'.		
Note 2. Where permanent ballast is fitted, samples of ballast are to be removed for examination of the structure underneath. The condition of the exposed structure is to be to the satisfaction of the Surveyor.		

5.3.6 The anchors are to be examined, the chain cables are to be ranged and they are to be examined together with the chain locker (*see Table 3.5.1 Survey preparation*) and clench plate. If any length of chain cable is found to be reduced in mean diameter at its most worn part by 12 per cent or more from its nominal diameter, it is to be renewed. Cables are to be changed 'end-for-end'. Anchor handling arrangements are to be examined.

5.3.7 Representative fastenings on the weatherdecks, e.g. for guardrails and spurnwaters, are to be tested to ascertain their soundness and may require to be drawn for examination at the discretion of the Surveyor.

5.3.8 When applicable, the Surveyor is to be satisfied as to the efficient condition of the means of escape from crew spaces, and spaces in which crew are normally employed.

5.3.9 The hand pumps, suctions, watertight doors, air and sounding pipes are to be examined. In addition, the Surveyor is to examine internally air pipe heads in accordance with the requirements of *Table 3.5.3 Air pipe head internal examination requirements*.

5.4 Examination and testing – Additional items for steel ships

5.4.1 The requirements for tank internal examination are given in *Table 3.5.2 Tank internal examination requirements for steel ships*.

5.4.2 In salt-water ballast spaces, integral sanitary tanks and bilges where the protective coating is found to be other than in GOOD condition as defined in *Vol 1, Pt 1, Ch 3, 1.5 Definitions 1.5.10* and it has not been repaired, maintenance of class will be subject to the spaces in question being internally examined and gauged.

5.4.3 The protection of steelwork, other than as referred to in *Vol 1, Pt 1, Ch 3, 5.4 Examination and testing – Additional items for steel ships 5.4.2* should be examined and made good where necessary on satisfactory completion of the survey. In areas where the inner surface of the bottom plating is covered with cement, asphalt or other composition, the removal of this covering may be dispensed with, provided that it is found sound and adhering satisfactorily to the steel.

Table 3.5.2 Tank internal examination requirements for steel ships

Tank	Special Survey I (Ship 6 years old)	Special Survey II (Ship 12 years old)	Special Survey III (Ship 18 years old)	Special Survey IV (Ship 24 years old)	All Subsequent Special Surveys
Peaks	All tanks	All tanks	All tanks	All tanks	All tanks
Salt-water ballast	All tanks	All tanks	All tanks	All tanks	All tanks
Lubricating oil	None	None	None	*See* Notes 1 and 2 One tank	One tank
Fresh water	None	One tank	All tanks	*See* Notes 1 and 2 All tanks	All tanks
Fuel oil — in way of					
(i) Machinery space	None	None	One tank	One tank	One tank
(ii) Supply (Replenishment) Oil Area	None	One tank	Two tanks — *see* Note 3	50% of tanks — *see* Notes 3 & 4	50% of tanks — *see* Notes 3 & 4
Fuel oil (water compensated)	All tanks	All tanks	All tanks	All tanks	All tanks
Sanitary	All tanks	All tanks	All tanks	All tanks	All tanks

Note 1. The above requirements apply to integral tanks only.

Note 2. Where a selected number of tanks is examined, then different tanks are to be examined at each Special Survey on a rotational basis.

Note 3. To include one deep tank, if any.

Note 4. Where 50% of tanks is to be examined, a minimum of two tanks are required to be examined depending upon the overall number of tanks.

Note 5. When examining tanks internally the Surveyor is to verify that striking plates or other additional reinforcement are fitted under sounding pipes. In the case of tanks only with remote gauging facilities, the satisfactory operation of the gauges is to be confirmed.

Note 6. Particular care must be taken in examining structure under suctions.

Note 7. Where testing is required, a functional test may be acceptable at the Surveyor's discretion.

Table 3.5.3 Air pipe head internal examination requirements

Special Survey I (Ships 6 years old)	Special Survey II (Ships 12 years old)	Special Survey III (Ships 18 years old) and subsequent
(1) Two air pipe heads (one port and one starboard) on exposed decks in the forward 0,25*L*. *See* Notes 1 to 5	(1) All air pipe heads on exposed decks in the forward 0,25*L*. *See* Notes 1 to 5	All air pipe heads on exposed decks in the forward 0,25*L*.*See* Notes 1 to 6
(2) Two air pipe heads (one port and one starboard) on the exposed decks, serving spaces aft of 0,25*L*. *See* Notes 1 to 5	(2) At least 20% of air pipe heads on exposed decks, serving spaces aft of 0,25*L*. *See* Notes 1 to 5	
Note 1. Air pipe heads serving ballast tanks are to be selected where available.		
Note 2. The Surveyor is to select which air pipe heads are to be examined.		
Note 3. Where considered necessary by the Surveyor as a result of the examinations, the extent of examinations may be extended to include other air pipe heads on exposed decks.		
Note 4. Where the inner parts of the air pipe head cannot be properly examined due to its design, it is to be removed in order to allow an internal examination.		
Note 5. Particular attention is to be given to the condition of the zinc coating in heads constructed from galvanised steel.		
Note 6. Exemption may be considered for air pipe heads where there is documented evidence of their replacement within the previous six years.		

5.4.4 Wood deck sheathing is to be examined and the caulking is to be tested and recaulked as necessary. If decay or rot is found, or the wood is excessively worn, the wood is to be renewed. Attention is to be given to the condition of the plating under wood deck sheathing or other deck covering. If it is found that such coverings are broken, or are not adhering closely to the plating, sections are to be removed as necessary to ascertain the condition of the plating, *see also Vol 1, Pt 1, Ch 3, 1.2 Surveys for damage or alterations 1.2.1*.

5.4.5 The structure in way of bimetallic connections, e.g. to aluminium alloy deck-houses, is to be examined and the efficiency of the insulation arrangements confirmed.

5.5 Examination and testing – Additional items for composite ships

5.5.1 The bonded attachments of frames, floors, bulkheads, structural joinery, engine bearers, sterntubes, rudder tubes, and integral tank boundaries are to be examined.

5.5.2 The hull to deck joint, together with any joints between the deck and deck-houses or superstructures, is to be examined.

5.5.3 The structure in way of the bolted attachment of fittings including guardrail stanchions, capstan/windlass, shaft brackets, fendering, mooring bitts, etc is to be examined.

■ *Section 6*
Special Survey – Thickness measurement requirements for steel ships

6.1 General

6.1.1 Thickness measurement requirements for steel ships are stated in Tables *Table 3.6.1 Thickness measurement of steel ships* and *Table 3.6.2 Thickness measurement - Additional requirements in way of structure identified with substantial corrosion*. *See also Vol 1, Pt 1, Ch 3, 1.8 Thickness measurement at surveys*.

6.1.2 Thickness measurements may be carried out in association with the fifth Annual Survey.

6.1.3 In areas where substantial corrosion, as defined in *Vol 1, Pt 1, Ch 3, 1.5 Definitions*, has been noted, then additional measurements are to be carried out, as applicable, in accordance with *Table 3.6.2 Thickness measurement - Additional requirements in way of structure identified with substantial corrosion* to determine the full extent of the corrosion pattern.

6.1.4 Where substantial corrosion is identified and not rectified, this will be subject to re-examination and gauging as necessary at Annual and Intermediate Surveys.

6.1.5 At each Special Survey, thickness measurements are to be taken in way of critical areas, as considered necessary by the Surveyor. Critical areas are to include locations throughout the ship that show substantial corrosion and/or are considered prone to rapid wastage.

6.1.6 The Surveyor may extend the scope of thickness measurement if deemed necessary.

Table 3.6.1 Thickness measurement of steel ships

Special Survey I (Ship 6 years old)	Special Survey II (Ship 12 years old)	Special Survey III (Ship 18 years old)	Special Survey IV and subsequent (Ship 24 years old and over)
(1) Bottom and lower parts of chain locker. (2) Critical and Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition.	(1) Wind and water strakes in way of 0,5*L* amidships. (2) Bottom and lower parts of chain locker. (3) Critical and Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition.	(1) Weatherdeck plating under wood deck planking or sheathing (2) Shell plating in way of the waterline throughout the length of the ship. (3)Two complete transverse sections of deck and shell plating within 0,5*L* amidships, one of which should be in way of a machinery space (4) Bottom and lower parts of chain locker. (5) Critical and Suspect areas, as required by the Surveyor and may include areas where the coatings are found to be other than in GOOD condition.	(1) All weatherdeck plating outside deck-houses or superstructures and including plating under wood deck planking or sheathing. (2) Shell plating in way of, and below, the waterline throughout the length of the ship. (3) Two complete transverse sections of deck and shell plating within 0,5*L* amidships, one of which should be in way of a machinery space. (4) Bottom and lower parts of chain locker. (5) Critical and Suspect areas, as required by the Surveyor and to include as applicable: (a) Areas where the coatings are found to be other than in GOOD condition. (b) Bottom shell in way of any cement, asphalt, ballast or other composition. (c) Deck plating and side shell plating in way of galleys, washrooms and refrigerated store spaces and any other wet spaces. (d) Structure in way of integral sanitary tanks.
Note *See Vol 1, Pt 1, Ch 3, 1.5 Definitions 1.5.9* for the definition of GOOD condition.			

Table 3.6.2 Thickness measurement - Additional requirements in way of structure identified with substantial corrosion

Structural member	Extent of measurement	Pattern of measurement
Plating	Suspect areas and adjacent plates	5 point pattern over 1 m^2
Stiffeners	Suspect areas	3 measurements each in line across web and flange

6.2 Thickness measurement reporting

6.2.1 A report is to be prepared by the approved company carrying out the thickness measurement. The report is to give the location of measurement, the thickness measured as well as the corresponding original thickness. The report is to give the date when the measurement was carried out, the type of measuring equipment, names of personnel and their qualifications and is to be signed by the operator.

6.2.2 The thickness measurement report is to be verified and signed by the Surveyor, and included with the Surveyor's report.

Section 7
Machinery survey – General requirements

7.1 Annual, Intermediate and Docking Survey

7.1.1 For Annual, Intermediate and Docking Surveys, *see Vol 1, Pt 1, Ch 3, 2 Annual Surveys – Hull, machinery and optional requirements*, *Vol 1, Pt 1, Ch 3, 3 Intermediate Surveys – Hull and machinery requirements* and *Vol 1, Pt 1, Ch 3, 4 Docking Surveys and In-water Surveys*

7.2 Complete Survey

7.2.1 While the ship is in dry dock, all openings to the sea in the machinery spaces, together with the valves, cocks and the fastenings with which these are connected to the hull, are to be examined.

7.2.2 All shafts (except screwshafts and tube shafts, for which special arrangements are detailed in *Vol 1, Pt 1, Ch 3, 13 Screwshafts, tube shafts and propellers*), thrust block and all bearings are to be examined. The lower halves of bearings need not be exposed if alignment and wear are found to be acceptable.

7.2.3 An examination is to be made of all reduction gears complete with all wheels, pinions, shafts, bearings and gear teeth, thrust bearings and incorporated brake and clutch arrangements where fitted.

7.2.4 The following auxiliaries and components are also to be examined:

(a) Auxiliary engines, auxiliary air compressors with their intercoolers, filters and/or oil separators and safety devices, and all pumps and components used for Mobility or Ship Type systems.
(b) Steering machinery.
(c) Windlass and associated driving equipment, where fitted.
(d) The holding down bolts, chocks of main and auxiliary engines, gearcases, thrust blocks and intermediate shaft bearings.
(e) Evaporators (other than those of vacuum type) and their safety valves, which should be seen in operation under steam.

7.2.5 All Ancillary systems are to be examined to ensure that there have been no modifications to the system that change the category, and no degradation that impacts on other systems or basic conditions on board.

7.2.6 All air receivers for Mobility or Ship Type systems, together with their mountings, valves and safety devices, are to be cleaned internally and examined internally and externally. If internal examination of the air receivers is not practicable, they are to be tested hydraulically to 1,3 times the working pressure.

7.2.7 The valves, cocks and strainers of the bilge and salvage system including bilge injection, are to be opened up as considered necessary by the Surveyor and together with pipes, are to be examined and tested under working conditions. The fuel oil, feed, lubricating oil and cooling water systems, also the ballast connections together with all pressure filters, heaters and coolers used for Mobility or Ship Type systems, are to be opened up and examined or tested, as considered necessary by the Surveyor. All safety devices for the foregoing items are to be examined.

7.2.8 Fuel tanks which do not form part of the ship's structure are to be examined, and if considered necessary by the Surveyor, they are to be tested to the pressure specified for new tanks. The tanks need not be examined internally at the first survey if they are found satisfactory on external inspection. The mountings, fittings and remote controls of all fuel oil tanks are to be examined, so far as is practicable.

7.2.9 Where remote and/or automatic controls are fitted for Mobility or Ship Type System, they are to be tested to demonstrate that they are in good working order.

7.2.10 In addition to the above, detailed requirements for steam and gas turbines, oil engines, electrical installations and boilers are given in *Vol 1, Pt 1, Ch 3, 8 Turbines – Detailed requirements*,*Vol 1, Pt 1, Ch 3, 9 Reciprocating internal combustion engines – Detailed requirements*, *Vol 1, Pt 1, Ch 3, 10 Electrical equipment* and *Vol 1, Pt 1, Ch 3, 11 Boilers* respectively. In certain instances, upon application by the Owner or where indicated by the maker's servicing recommendations, LR will give consideration to the circumstances where deviation from these detailed requirements is warranted, taking account of design, appropriate indicating equipment (e.g. vibration indicators) and operational records.

7.2.11 Where machinery installation includes a 'lifed item' the requirements of *Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.21* are applicable.

Section 8
Turbines – Detailed requirements

8.1 Complete Survey

8.1.1 The requirements of *Vol 1, Pt 1, Ch 3, 7 Machinery survey – General requirements* are to be complied with.

8.1.2 The following parts are to be opened out and examined:

(a) The working parts of the main turbines and of auxiliary machinery used for essential services, including bulkhead stop valves, manoeuvring valves, the blading, rotors, flexible couplings and casings.

8.1.3 In gas turbines the following parts are to be opened out and examined:

(a) The impellers or blading, rotors and casings of the air compressors, the combustion chambers, burners, intercoolers, heat exchangers, gas and air piping and fittings, starting and reversing arrangements.

8.1.4 Condensers, steam reheaters, desuperheaters which are not incorporated in the boilers, and any other appliances used for Mobility or Ship Type systems, are to be examined to the satisfaction of the Surveyor, and if it is considered necessary, they are to be tested.

8.1.5 The manoeuvring of the turbines is to be tested under working conditions.

8.2 Turbine condition monitoring (TCM)

8.2.1 Where the main propulsion steam turbines are provided with approved vibration monitoring equipment, a machinery notation **TCM** (Turbine Condition Monitoring) may be assigned provided that the following conditions are complied with:

(a) Vibration measurements recorded with equipment acceptable to LR are to be taken at regular intervals not exceeding six months. The records are to be retained on board and be available to the LR Surveyors for assessment at time of survey.
(b) Rotor position indicators are to be installed permanently on each turbine. Records of these readings are to be retained on board the ship for inspection by the LR Surveyor at time of survey.

8.2.2 For maintenance of the **TCM** notation, the records of vibration monitoring and rotor position readings are to be audited annually.

8.2.3 In addition to the vibration readings at the time of the survey, it is necessary to carry out a full power trial to demonstrate to the LR Surveyor that the turbines are in good working order.

8.2.4 Where the notation **TCM** has been assigned the main steam turbine top casings need not be lifted for examination of the rotors and diaphragms as required by *Vol 1, Pt 1, Ch 3, 8.1 Complete Survey 8.1.2* provided the condition monitoring data are found within limits set by acceptance standards. The remaining requirements of *Vol 1, Pt 1, Ch 3, 8.1 Complete Survey 8.1.2* are to be complied with. Where the Surveyor considers that the data presented is not entirely to his satisfaction, the top casing will be required to be lifted.

Section 9
Reciprocating internal combustion engines – Detailed requirements

9.1 Scope

9.1.1 The requirements of this Section are applicable to reciprocating internal combustion engines, operating on liquid, gas or dual fuel, providing power for Mobility or Ship Type systems.

9.2 Complete Survey

9.2.1 The requirements of *Vol 1, Pt 1, Ch 3, 7 Machinery survey – General requirements* are to be complied with.

9.2.2 The following parts are to be opened out and examined:

(a) Cylinders, covers, valves and valve gear, pistons and piston rods, crossheads, guides, connecting rods and crankshafts and all bearings, crankcases, bedplates, entablatures, crankcase door fastenings and explosion relief devices, scavenge relief devices, scavenge pumps, scavenge blowers, superchargers and their associated coolers, air compressors and their intercoolers, filters and/or separators and safety devices, fuel pumps and fittings, camshaft drives and balancer units, vibration dampers or detuners, flexible couplings and clutches, reverse gears, attached pumps and cooling arrangements.

9.2.3 Selected pipes in the starting air system are to be removed for internal examination and are to be hammer tested. If any appreciable amount of lubricating oil is found in the pipes, the starting air system is to be thoroughly cleaned internally by steaming out, or other suitable means. Some of the pipes selected are to be those adjacent to the starting air valves at the cylinders and to the discharges from the air compressors. This requirement is only applicable to oil engines using compressed air directly into individual cylinders through starting air valves, it is not applicable to air motor starting systems.

9.2.4 The manoeuvring of engines is to be tested under working conditions. Initial starting arrangements are to be tested.

9.2.5 Where steam is used for Mobility or Ship Type systems, the condensing plant, feed pumps and fuel oil burning plant are to be examined and the steam pipes examined and tested as detailed in *Vol 1, Pt 1, Ch 3, 12 Steam pipes*

■ *Section 10*
Electrical equipment

10.1 Annual and Intermediate Surveys

10.1.1 The electrical contacts of air circuit-breakers are to be visually inspected and maintained in accordance with the manufacturer's recommendations by suitably qualified and trained personnel. Appropriate maintenance records are to be made available to the attending Surveyor on request.

10.1.2 The requirements of*Vol 1, Pt 1, Ch 3, 2.3 Machinery* and*Vol 1, Pt 1, Ch 3, 3.3 Machinery* are to be complied with as far as applicable.

10.2 Complete Surveys

10.2.1 An electrical insulation resistance test is to be made on the electrical equipment and cables. The installation may be sub-divided, or equipment which may be damaged disconnected, for the purpose of this test.

10.2.2 The fittings on the main and emergency switchboards, section boards and distribution boards are to be examined and over-current protective devices and fuses inspected to verify that they provide suitable protection for their respective circuits.

10.2.3 Generator circuit-breakers are to be tested, so far as is practicable, to verify that protective devices including preference tripping relays, if fitted, operate satisfactorily.

10.2.4 Air circuit-breakers for essential or emergency services and rated at 800 A and above are to be inspected to ensure that the manufacturer's recommended number of switching options has not been exceeded. *See Vol 2, Pt 9, Ch 3, 5.3 Circuit-breakers 5.3.6*. Where a breaker is not fitted with an automatic counter, a written record is to be kept.

10.2.5 The electric cables and their securing arrangements are to be examined, so far as is practicable, without undue disturbance of fixtures or casings unless opening up is considered necessary as a result of observation or of the tests required by *Vol 1, Pt 1, Ch 3, 10.2 Complete Surveys 10.2.1* The Surveyor is also to be satisfied regarding the condition of glands at watertight and gastight bulkheads.

10.2.6 The generator prime movers are to be surveyed as required by *Vol 1, Pt 1, Ch 3, 8 Turbines – Detailed requirements* and *Vol 1, Pt 1, Ch 3, 9 Reciprocating internal combustion engines – Detailed requirements* and the governing of the engines tested. The motors concerned with essential services together with associated control and switch gear are to be examined and if considered necessary, are to be operated, so far as is practicable, under working conditions. All generators and steering gear motors are to be examined and are to be operated under working conditions, though not necessarily under full load or simultaneously.

10.2.7 Where transformers associated with supplies to essential services are liquid immersed, the Owner is to arrange for samples of the liquid to be taken and tested for dissolved gases, breakdown voltage, acidity and moisture, by a competent authority, in accordance with the equipment manufacturer's requirements, and a certificate giving the test results is to be made available to the Surveyor on request.

10.2.8 Navigation light indicators are to be tried under working conditions, and correct operation on the failure of supply or failure of navigation lights verified.

10.2.9 The emergency sources of electrical power, where fitted, together with their automatic arrangements and associated circuits are to be tested.

10.2.10 Emergency lighting, transitional emergency lighting, supplementary emergency lighting, general emergency alarm and public address systems are to be tested as far as practicable.

10.2.11 Where the ship is electrically propelled, the propulsion motors, generators, propulsion transformers, propulsion conversion equipment, cables, harmonic filters, neutral earthing resistors, dynamic braking resistors and all ancillary electrical equipment that forms part of the propulsion drive and control system, exciters and ventilating plant (including coolers) associated therewith are to be surveyed, and the insulation resistance to earth is to be tested. Special attention is to be given to windings, commutators and sliprings. Where practicable, the low voltage and high voltage windings of cast resin propulsion transformers are to be subjected to boroscopic inspection, to assess the physical condition of their insulation and for signs of mechanical and thermal damage. The operation of protective gear and alarm devices is to be checked, so far as is practicable. Insulating oil, if used, is to be tested in accordance with *Vol 1, Pt 1, Ch 3, 10.2 Complete Surveys 10.2.7*. Interlocks intended to prevent unsafe operations or unauthorised access are to be checked to verify that they are functioning correctly. Emergency overspeed governors are to be tested.

10.2.12 A General Examination of the electrical equipment in areas which may contain flammable gas or vapour and/or combustible dust is to be made to ensure that the integrity of the safe type electrical equipment has not been impaired owing to corrosion, missing bolts, etc. and that there is not an excessive build-up of dust on or in dust protected electrical equipment. Cable runs are to be examined for sheath and armouring defects, where practicable, and to ensure that the means of supporting the cables are in good order. Tests are to be carried out to demonstrate the effectiveness of bonding straps for the control of static electricity. Alarms and interlocks associated with pressurised equipment or spaces are to be tested for correct operation.

■ *Section 11* Boilers

11.1 Frequency of survey

11.1.1 All boilers, economisers, steam receivers, steam heated steam generators, thermal oil and hot water units intended for Mobility or Ship Type systems, together with boilers used exclusively for Ancillary systems having a working pressure exceeding 3,4 bar and a heating surface exceeding 4,65 m^2 are to be surveyed at intervals not exceeding 3 years and generally examined externally at the time of the Annual Survey of the ship.

11.2 Scope of surveys

11.2.1 At the surveys described in *Vol 1, Pt 1, Ch 3, 11.1 Frequency of survey* the boilers, superheaters, economisers and air heaters are to be examined internally and externally and where considered necessary, the pressure parts are to be tested by hydraulic pressure and the thickness of plates and tubes and sizes of stays are to be ascertained to determine a safe working pressure. The principal mountings on boilers, superheaters and economisers are to be opened up and examined and the safety valves are to be set under steam to a pressure not greater than the approved design pressures of the respective parts. As a working tolerance, the setting is acceptable provided that the valves lift at not more than 103 per cent of the approved design pressure. The remaining mountings are to be examined externally and if considered necessary by the Surveyor, are to be opened up for internal examination. Collision chocks, rolling stays and boiler stools are to be examined and maintained in an efficient condition.

11.2.2 In fired boilers employing forced circulation, the pumps used for this service are to be opened and examined at each Boiler Survey.

11.2.3 The fuel oil burning system is to be examined under working conditions and a General Examination made of fuel tank valves, pipes, deck controlgear and oil discharge pipes between pumps and burners.

11.2.4 At each survey of a cylindrical boiler which is fitted with smoke tube superheaters, the saturated steam pipes are to be examined as detailed in *Vol 1, Pt 1, Ch 3, 12 Steam pipes*.

11.2.5 At the Annual General Examination referred to in *Vol 1, Pt 1, Ch 3, 11.1 Frequency of survey 11.1.1* the requirements of *Vol 1, Pt 1, Ch 3, 2.3 Machinery 2.3.7* and *Vol 1, Pt 1, Ch 3, 2.3 Machinery 2.3.8* are to be complied with

Section 12
Steam pipes

12.1 Frequency of survey

12.1.1 Saturated steam pipes, also superheated steam pipes where the temperature of the steam at the superheater outlet is not over 450ºC, are to be surveyed 12 years from the date of build (or installation) and thereafter at six-yearly intervals.

12.1.2 Superheated steam pipes where the temperature of the steam at the superheater outlet is over 450ºC are to be surveyed after six years from the date of build (or installation) thereafter at six-yearly intervals.

12.1.3 At 12 years from the date of build (or installation) thereafter at six-yearly intervals, all copper or copper alloy steam pipes over 76 mm external diameter supplying steam for essential services at sea, are to be hydraulically tested to twice the working pressure.

12.2 Scope of surveys

12.2.1 At each survey a selected number of main steam pipes, also of auxiliary steam pipes, which:

(a) are over 76 mm external diameter;
(b) supply steam for essential services at sea; and
(c) have bolted joints,

are to be removed for internal examination and are to be hydraulically tested to 1,5 times the working pressure. If these selected pipes are found satisfactory in all respects, the remainder need not be tested. So far as is practicable, the pipes are to be selected for examination and hydraulic test in rotation so that in the course of the surveys all sections of the pipeline will be tested.

12.2.2 Where main and/or auxiliary steam pipes of the category described in *Vol 1, Pt 1, Ch 3, 12.2 Scope of surveys 12.2.1* and *Vol 1, Pt 1, Ch 3, 12.2 Scope of surveys 12.2.1* have welded joints between the lengths of pipe and/or between pipes and valves, the lagging in the way of the welds is to be removed, and welds examined and if considered necessary by the Surveyor, crack detected. Pipe ranges having welded joints are to be hydraulically tested to 1,5 times the working pressure. Where lengths having ordinary bolted joints are fitted in such pipe ranges and can be readily disconnected, they are to be removed for internal examination and hydraulically tested to 1,5 times the working pressure.

12.2.3 Where, on cylindrical boilers having smoke tube superheaters, the saturated steam pipes adjoining the saturated steam headers are situated partly in the boiler smoke boxes, all such pipes adjoining and cross-connecting these headers in the smokeboxes are, at the surveys required by *Vol 1, Pt 1, Ch 3, 12.1 Frequency of survey* to be included in the pipes selected for examination and testing as defined in *Vol 1, Pt 1, Ch 3, 12.2 Scope of surveys 12.2.1*. Where the saturated steam pipes inside the smoke boxes consist of steel castings of substantial construction, these requirements need only to be applied to a sample casting. Where steel castings are not fitted, the Surveyor is to satisfy himself of the condition of the ends of the saturated steam pipes in the smoke boxes at each Boiler Survey and if he considers it necessary, a sample pipe is to be removed for examination.

12.2.4 At the surveys specified in *Vol 1, Pt 1, Ch 3, 12.1 Frequency of survey 12.1.3*, any of the copper or copper alloy pipes, such as those having expansion or other bends, which may be subject to bending and/or vibration, also closing lengths adjacent to steam driven machinery, are to be annealed before being tested.

12.2.5 Where it is inconvenient for the Owner to fulfil all the requirements of a Steam Pipe Survey at its due date, LR will be prepared to consider postponement of the survey, either wholly or in part.

Section 13
Screwshafts, tube shafts and propellers

13.1 Frequency of surveys

13.1.1 Shafts with keyed propeller attachments and fitted with continuous liners or approved oil glands, or made of approved corrosion resistant materials, are to be surveyed at intervals of six years when the keyway complies fully with the present Rules.

13.1.2 Shafts having keyless type propeller attachments are to be surveyed at intervals of six years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

13.1.3 Shafts having solid coupling flanges at the after end are to be surveyed at intervals of six years provided they are fitted with approved oil glands or are made of approved corrosion resistant materials.

13.1.4 All other shafts not covered by *Vol 1, Pt 1, Ch 3, 13.1 Frequency of surveys 13.1.1* are to be surveyed at intervals of 3 years.

13.1.5 Controllable pitch propellers for main propulsion purposes are to be surveyed at the same intervals as the screwshaft.

13.1.6 Directional propeller and podded propulsion units for main propulsion purposes are to be surveyed at intervals not exceeding six years.

13.1.7 Water jet units for main propulsion purposes are to be surveyed at intervals not exceeding six years provided the impeller shafts are made of approved corrosion resistant material or have approved equivalent arrangements.

13.1.8 Thruster-assisted mooring and athwartship thrust propellers and shaftings are to be surveyed at intervals not exceeding six years.

13.2 Normal surveys

13.2.1 All screwshafts are to be withdrawn for examination by LR Surveyors at the intervals prescribed in *Vol 1, Pt 1, Ch 3, 13.1 Frequency of surveys 13.1.1*. The after end of the cylindrical part of the shaft and forward one third of the shaft cone, or fillet of the flange, is to be examined by a magnetic particle crack detection method. In the case of a keyed propeller attachment at least the forward one third of the shaft cone is to be examined with the key removed. Weardown is to be measured and the sterntube bearings, oil glands, propellers and fastenings are to be examined. Controllable pitch propellers where fitted are to be opened up and the working parts examined, together with the controlgear.

13.2.2 Directional propeller and podded propulsion units are to be generally examined so far as possible, including the propellers, shafts, gearing, controlgear and primary electrical components, inclusive of control and protection devices. When and where access panels or plugs avail themselves and units integrity not compromised by leakage if unit afloat, then these should be opened to allow inspection.

13.2.3 Water Jet Units are to be generally examined so far as possible, including the impeller, casing, shaft, shaft seal, shaft bearing, inlet and outlet channels, steering nozzle, reversing arrangements, and controlgear. Consideration should be given to performance and operational data of unit when assessing its efficiency for further service. Any available inspection panels or plugs should be utilised as considered necessary in this general examination of subject item.

13.2.4 Thruster-assisted mooring and athwartship thrust propellers are to be generally examined in dry dock. All accessible parts, including sealing, locking and bearing faces and any other moving parts should be examined. Non-destructive examination should be carried out as considered necessary by the surveyor on blade/fin roots. Consideration may be given to appropriate condition monitoring scheme data for determining the condition of the unit whilst in afloat condition.

13.2.5 Podded propulsion unit screwshaft roller bearings are to be renewed when the residual calculated life at the maximum continuous rating at time of survey no longer exceeds the survey interval. *See Vol 2, Pt 4, Ch 4, 6.3 Propulsion shafting 6.3.8*.

13.2.6 On completion, directional propeller and podded propulsion units, water jet units, dynamic positioning and/or thruster-assisted mooring systems and athwartship thrust propellers are to be tested under working conditions afloat for satisfactory operation.

13.2.7 Stationary supporting structure and any erosion protection inserts or doublers should be examined in way of any propulsion devices.

13.3 Screwshaft Condition Monitoring (SCM)

13.3.1 Monitoring records are to be reviewed at annual survey for all vessels assigned the notation **SCM** (Screwshaft Condition Monitoring). The records that are to be maintained for oil and water lubricated bearings are detailed in the following Sections.

13.3.2 Oil lubricated bearing records are to be available on board that include the following:

(a) Lubricating oil analysis to be carried out regularly at intervals not exceeding six months. Each analysis is to include the following minimum parameters:

- Water content.
- Chloride content.

- Bearing material and metal particles content.
- Oil ageing (resistance to oxidation), minimum testing to include Viscosity and Total Acid Number (TAN).

Note Oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube.

(b) Oil consumption.

(c) Bearing temperatures under sea going conditions.

13.3.3 Water lubricated bearing records are to be available on board that include the following:

(a) A record of variations in the flow rate of lubricating water.

(b) A record of variations in the shaft power transmission.

(c) Wear monitoring records for the sternbush.

(d) For open loop systems the records from equipment for continuous monitoring of water sediment or alternatively records from an LR approved extractive sampling and testing procedure are to be available on board. Records of cleaning and replacement of lubrication filters/separators are to be maintained on board. The pumping and water filtration system is to be considered part of the continuous survey cycle and is to be subject to a Periodical Survey.

(e) For closed cycle water systems, the records from water analysis results carried out regularly at intervals not exceeding six months are to be retained on board. The analysis is to include the following parameters;

(i) Chloride content

(ii) Bearing material and metal particles content.

Note Samples are to be taken under service conditions and are to be representative of the water circulating within the sterntube. Records of cleaning and replacement of lubrication filters/separators are to be maintained on board. The pumping and water filtration system is to be considered part of the continuous survey cycle and is to be subject to a Periodical Survey.

13.3.4 For maintenance of the **SCM** notation, the records of all data collected in *Vol 1, Pt 1, Ch 3, 13.3 Screwshaft Condition Monitoring (SCM) 13.3.2* and *Vol 1, Pt 1, Ch 3, 13.3 Screwshaft Condition Monitoring (SCM) 13.3.3* are to be retained on board and audited annually.

13.3.5 Where the requirements for the notation **SCM** have been complied with, the screwshaft need not be withdrawn at surveys as required by *Vol 1, Pt 1, Ch 3, 13.2 Normal surveys 13.2.1* provided all condition monitoring data are found to be within permissible limits and all exposed areas of the shaft are examined by a magnetic particle crack detection method or an alternative approved means for shafts with a protective liner, or coating (*see Vol 2, Pt 3, Ch 2, 5.2 Screwshaft Condition Monitoring (SCM) 5.2.3*. The remaining requirements of *Vol 1, Pt 1, Ch 3, 13.2 Normal surveys 13.2.1* are to be complied with. Where the attending Surveyor considers that the data presented is not sufficient to determine the condition of the shaft, the shaft may be required to be withdrawn in accordance with *Vol 1, Pt 1, Ch 3, 13.2 Normal surveys 13.2.1*. For water lubricated bearings, the screwshaft is to be withdrawn for examination, as *Vol 1, Pt 1, Ch 3, 13.2 Normal surveys 13.2.1*, when the ship reaches 18 years from the date of build or the 3rd Special Survey, whichever comes first.

13.4 Modified Survey

13.4.1 A Modified Survey may be accepted at alternate six-yearly surveys for shafts described in *Vol 1, Pt 1, Ch 3, 13.1 Frequency of surveys 13.1.1* provided they are fitted with oil lubricated bearings and approved oil glands, and also for those in *Vol 1, Pt 1, Ch 3, 13.1 Frequency of surveys 13.1.2* and *Vol 1, Pt 1, Ch 3, 13.1 Frequency of surveys 13.1.3*.

13.4.2 The Modified Survey is to consist of the partial withdrawal of the shaft, sufficient to ascertain the condition of the stern bearing and shaft in way. For keyless propellers or shafts with a solid flange connection to the propeller a visual examination to confirm the good condition of the sealing arrangements is to be made. The oil glands are to be capable of being replaced without removal of the propeller. The forward bearing and all accessible parts including the propeller connection to the shaft are to be examined as far as possible. Weardown is to be measured and found satisfactory. Where a controllable pitch propeller is fitted, at least one of the blades is to be dismantled complete for examination of the working parts and the controlgear.

13.4.3 For keyed propellers, the after end of the cylindrical part of the shaft and forward one third of the shaft cone is to be examined by a magnetic particle crack detection method, for which dismantling of the propeller and removal of the key will be required.

13.4.4 Where the notation **SCM** has been assigned as described in *Vol 1, Pt 1, Ch 3, 13.3 Screwshaft Condition Monitoring (SCM) 13.3.1* and all data is found to be within permissible limits, partial withdrawal of the shaft may not be required. Where doubt exists regarding any of the above findings the shaft is to be withdrawn to permit an entire examination.

13.5 Partial Survey

13.5.1 For shafts where the Modified Survey is applicable, upon application by the Owner, LR will be prepared to give consideration to postponement of the survey for a maximum period of half the specified cycle provided a Partial Survey is held.

13.5.2 The Partial Survey is to consist of the propeller being backed off in any keyed shaft and the top half of the cone examined by an efficient crack detection method for which removal of the key will be required. Oil gland and seals are to be examined and dealt with as necessary. Weardown is to be measured and found satisfactory. Propeller and fastenings are to be examined.

13.5.3 LR will be prepared to give consideration to the circumstances of any special case upon application by the Owner.

■ *Section 14*
Hull planned maintenance – HPMS

14.1 Introduction

14.1.1 Within the scope of *Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.12* an approved Hull Planned Maintenance Scheme (HPMS) can be accepted as an integral part of LR’s Continuous Survey (CSH) cycle

14.1.2 The following improved facilities for dealing with hull structural surveys are provided through adoption of the Hull Planned Maintenance Scheme:

(a) A more flexible approach to dealing with Classification Surveys of selected hull structural items. Opening out for Classification inspection is restricted to mandatory items and to verify the efficiency of the scheme through annual and periodical audits. The condition as observed and reported by the ship's LR authorised staff will, subject to Annual Audit, be sufficient to credit the items for survey.

(b) The Navy can operate a single system, covering maintenance, spare parts/consumables supply and survey requirements for both hull and machinery items. The level of documentation and control will demonstrate a commitment to any Naval Authority requirements.

14.1.3 The Hull Planned Maintenance Scheme will operate by allowing LR authorised personnel to carry out inspections of selected hull items to an approved schedule of inspections over a six-year period corresponding to the naval ship classification cycles. Ships currently undertaking classification surveys by either SS or CSH regimes may be accepted onto the Scheme. In order to implement the scheme it will be necessary to divide the items selected for ship's staff inspection into a programme similar to that required for CSH in which approximately 17 per cent of hull master list items are inspected each year. In preparing this schedule of inspections, due account should be taken of the items still required to be surveyed by an LR Surveyor such that these may be conveniently carried out at the time of the Annual Audit or on completion of the CSH classification cycle.

14.2 Master list Items

14.2.1 A list of typical hull master list items that can be surveyed by authorised personnel, and those items that remain to be dealt with by LR Surveyors, can be obtained from LR’s London Office. It should be noted that LR will continue to inspect, as necessary, where there is a history of structural defects in a particular area, either on the ship or on a similar ship.

14.2.2 Where protective coating condition has been found to be poor or where substantial corrosion is identified in a tank or space scheduled for inspection by the ship's staff, a Memorandum will be imposed requiring that area to be examined and gauged at Annual Surveys by an LR Surveyor. Notwithstanding this requirement, the tank or space in question may continue to be inspected by the ship's staff subject to the agreement of the Scheme Manager.

14.3 Scheme Approval

14.3.1 It is recognised that planned maintenance systems may take various forms; the type of maintenance control, the scheduling, reporting and recording methods can only be decided by the Navy, having due regard to all the factors involved.

14.3.2 Approval of the planned maintenance scheme involves approval of the overall approach to maintenance for each installation, not just approval of the planned maintenance software. The amount of information to be submitted, however, can be reduced if the planned maintenance software has been approved using LR's *Software Conformity Assessment Scheme*. Further details can be obtained from LR's local offices.

14.3.3 Operational requirements for the approval of Hull Planned Maintenance Schemes are as follows:

(a) Ship to be operating the Continuous Survey Cycle for Hull **(CSH).** (Where the Naval Authority requirements preclude the operation of the ship on a continuous hull survey, an alternative arrangement of 'modified' Special Survey will be employed.)
(b) Ship to be operating an approved Machinery Planned Maintenance Scheme.
(c) All personnel operating the scheme to hold a valid LR *Certificate of Authorisation*.
(d) The language of the scheme to be English.
(e) The scheme is to be based on a computerised system and should have back-up devices, which are to be updated at regular intervals.
(f) Access to computerised systems for updating of the maintenance documentation and maintenance programme shall only be permitted by personnel with a valid *LR Certificate of Authorisation*.
(g) Approval of the scheme is required to be reconsidered if ownership or management of the ship changes.

14.3.4 Details to be submitted:

(a) A description of the scheme regarding its application on board ship and the proposed flow of maintenance documents and method of filing.
(b) A numbered index of the items is to be included in the scheme. This index is to include at least all hull items that appear on the 'Master List of Surveyable Items'. The scheme may also cover items that are not required for classification. The indexing system is to be such that ready cross-reference to the Master List numbers can be made.
(c) Sample job descriptions, and the time schedules for each item, are to be provided. Maintenance descriptions are to cover at least the minimum work necessary to demonstrate that a satisfactory examination of the item will be made. The extent of the work to be undertaken is to be indicated but it is not necessary for approval purposes to include every detailed job description. A selection of sample job descriptions will suffice to demonstrate how the system works.
(d) The reporting and recording procedures are to be sufficiently comprehensive to demonstrate that both the Navy and the LR Surveyor can verify correct operation of the planned maintenance scheme at the time of the Annual Audit. There is to be a system for reporting the following information to Navy and recording on board ship and at the Navy's headquarters:

- details of inspections carried out;
- the condition as found;
- any repairs or maintenance undertaken;

(e) The details of items inspected may be supplemented with digital photographs. These may be stored within the planned maintenance software or in a clearly distinguished and labelled electronic file system.

14.3.5 Where a ship is already operating an SS classification regime it will be necessary for the survey cycle to be converted to a CSH regime. Adoption of the scheme is best effected at the commencement of the next SS/CSH classification cycle. However, where a Navy wishes to enter the scheme in mid cycle this can be achieved by the following methods:

(a) Entry up to 2nd Annual Survey:

all hull master list items will require to be dealt with between date of entry and the SS/CSH due date;

(b) Entry following 2nd Annual Survey:

at least 17 per cent of the hull master list items to be dealt with in each full year of the SS/CSH cycle remaining, part years to be dealt with pro rata. The balance of hull master list items to complete the SS/CSH cycle will be dealt with by the LR Surveyor at SS/CSH due date.

14.3.6 Where entry is effected following the 2nd Annual Survey, the Navy may choose to deal with more than the minimum number of items as indicated above, in which case the number of items remaining to be dealt with by the LR Surveyor to complete the SS/CSH cycle can be reduced accordingly.

14.4 Roles and Responsibilities

14.4.1 **Navy.** The Navy should make a request for approval of the planned maintenance scheme either through a local LR office or direct to the London office. The information detailed in *Vol 1, Pt 1, Ch 3, 14.3 Scheme Approval 14.3.4* should be submitted. Requests for approval of planned maintenance software in accordance with *LR's Software Conformity Assessment Scheme* should be made to a local LR office or direct to the London office.

14.4.2 **Lloyd's Register.** The planned maintenance scheme will be reviewed and, if acceptable, a *Certificate of Operation* of an Approved Planned Maintenance Scheme for Hull Structures will be issued to the Navy. A copy of the Certificate is to be retained on board the subject ship for the information of the Commanding Officer, Marine Engineer Officer and LR's Surveyors. The **HPMS** notation will be assigned if requested and an appropriate memoranda item entered on the ship's survey status. The

Certificate of Operation will be valid until the end of the classification cycle and, on completion of a satisfactory audit, the attending Surveyor will reissue the certificate.

14.4.3 **Lloyd's Register Scheme Manager.** A Scheme Manager will be appointed by LR for each Navy with ships operating the Hull Planned Maintenance Scheme. The Scheme Manager will administer the scheme on an individual ship or group basis, act as a technical consultant to the Navy and train the ship's staff in the methods of hull structural inspection and reporting. He/she will be resident in either a terminal port that the ship uses regularly or the LR office that manages the Navy’s account. More details are given in the following paragraphs.

(a) Scheme Set-up

The Scheme Manager will, on obtaining a request from a Navy to include a ship on the Scheme:

- Identify the ship(s) to be assessed with the Navy.
- Contact LR's London Office for any special requirements. For example there may be specific areas where LR will not credit inspections by a ship's staff due to a history of defects.
- Guide the Navy through completion of the Hull Planned Maintenance Scheme implementation checklist and application form.
- Review ship's Master List of surveyable items to determine which items will be inspected by the ship's staff.
- Liaise with the Navy to determine a schedule of inspections to include the items to be inspected by a ship's staff and taking due account of the items still required to be surveyed by an LR Surveyor.
- Obtain scheme approval from the LR's London Office.
- Issue certification for the ship (i.e. *Certificate of Operation*).

(b) Training

The Scheme Manager will carry out the following actions associated with training:

- Prepare training documentation and training workshops.
- Deliver training to the ship's staff and issue certification (i.e. *Certificate of Authorisation*).
- Maintain the database of authorised ship's officers, available through Class Direct.
- Arrange for refresher training programmes for the ship's staff at six-yearly intervals.

(c) Scheme Operation

During operation, the Scheme Manager will act as the primary contact for Hull Planned Maintenance issues:

- Confirm operation of the scheme through contact with the Navy's office.
- Review and process ship's staff reports.
- Perform, where practicable, shipboard Annual Audit of the scheme.
- Where the shipboard Annual Audit is undertaken through another LR office, act as liaison and contact point for the local LR Surveyor.
- To assess progress of the scheme at the end of each survey cycle and report to LR's London Office and the Navy. Undertake a review at the end of the second survey cycle, i.e. when the ship is 12 years of age, and, if applicable, make a recommendation to the Classification Group in London that the ship be considered for extension of the scheme into the third cycle.

14.4.4 **Authorised Ship’s Personnel.** Authorised ship's personnel will carry out inspections of the hull structural items for which they are authorised, at sea or in port, whichever is the most convenient. Inspections of individual master list items are required to be carried out in accordance with the applicable requirements of LR's Rules for Naval Ships. The Commanding Officer and Navy should arrange for LR's Surveyors to carry out an Annual Audit of the hull maintenance records. Annual audits are to be held within three months before or after the due date and are to be harmonised with the Annual Classification Survey. Items to be credited for Class can be CSH items that have become due in the previous 12 months. In the case of new ships on their first survey cycle, approximately 17 per cent of the total number of CSH items are to be selected.

14.4.5 Requirements of the Intermediate Special Survey **(ITSS)** will still require to be satisfied, as applicable. Master list items dealt with by the ship's staff in the 12 months prior to ITSS may be considered for credit towards this survey and may not need to be re-examined by the LR Surveyor unless required as part of the Annual Audit.

14.4.6 At the Annual Audit, the maintenance records and associated documentation are to be made available, which should include:

- Inspection and maintenance records for each item to be credited for Class. These records should give details of any repairs carried out.
- Written details of any breakdown, malfunction or defect in hull structure. Such details should include the main cause of failure.

- An LR *Certificate of Authorisation* for all authorised personnel who have carried out maintenance work on items to be credited for Class.
- An LR *Certificate of Operation* of an Approved Planned Maintenance Scheme for Hull Structures.
- Confirmation of the type of planned maintenance software in use.
- Reports will be required to be forwarded to the Scheme Manager on a 3-monthly basis.

14.4.7 **Lloyd's Register Surveyors.** At the Annual Audit held concurrently with the Annual Classification Survey, the hull records and documentation will be examined in sufficient depth by the LR Surveyors to ensure that the scheme has been operated correctly and that structure and coatings/corrosion prevention systems have functioned satisfactorily since the previous Audit. The records should indicate that all scheduled maintenance has been carried out. Any items not dealt with as per the schedule will be discussed with the authorised personnel.

14.4.8 As part of the Audit the LR Surveyors may carry out a general examination of the hull structural items completed in the previous year. If the Surveyor is not satisfied with any aspect of the scheme's operation he/she may request that items be opened out for inspection.

14.4.9 If deficiencies in the operation of the scheme are identified, either from the maintenance records or from the general condition of the ship, the Surveyors may advise that a further Audit will be required and impose a suitable Condition of Class. In the event of serious deficiencies, a report will be forwarded to the Naval Ship Classification Committee in London recommending that the special arrangements for dealing with hull structural surveys be suspended.

14.4.10 The dates of items to be credited for Class will be aligned to the date of the Annual Audit, regardless of when the survey was carried out by the ship's staff. Any other surveyable items of hull structure not covered by the Scheme will be surveyed and credited in the normal way.

14.4.11 It should be noted that when items that the ship's staff are authorised to survey become due for survey between Annual Audits, they will be shown as 'OVERDUE' on the survey status until the Annual Audit has been held and reported.

14.4.12 Items approved for inspection by the ship's staff, but not inspected by them between Annual Audits according to the approved schedule of inspections, will require to be examined by the LR Surveyor at the time of the Annual Audit.

14.4.13 **Inspection Results and Reporting.** Results of the inspections carried out by authorised ship's staff in accordance with the approved schedule of inspection should be recorded on the report forms provided by LR and transmitted to the Scheme Manager at the required intervals. Where previously agreed with the Scheme Manager, alternative methods of reporting may be accepted.

14.4.14 Should the authorised ship's staff, during the course of their inspections, identify any defect or damage which could invalidate the conditions of class for which a vessel has been assigned, this should be reported to LR without delay. In such cases, an LR Surveyor should be requested to attend the ship to carry out an appropriate survey in accordance with normal practice. All repairs that may be required in order for the ship to maintain class are to be carried out to the satisfaction of an LR Surveyor. When repairs are effected at a port, terminal or location where the services of an LR Surveyor are not available, the repairs are to be surveyed by an LR Surveyor at the earliest opportunity thereafter.

■ *Section 15*
Machinery planned maintenance and condition monitoring, MPMS, MCM and RCM

15.1 Introduction

15.1.1 Within the scope of *Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.18* and *Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.19*, an approved Planned Maintenance Scheme (**MPMS**) and Condition Monitoring (**MCM**) can be accepted as an integral part of LR's Continuous Survey Machinery (**CSM**) cycle.

15.1.2 Planned maintenance systems may be based on calendar or running hours calling for items to be opened out for inspection and overhaul at specified periods. Alternatively the machinery may be monitored for condition and performance, whereby items need only be opened out for examination when readings indicate deterioration.

15.1.3 Navies who operate a planned maintenance scheme that meets the LR requirements will benefit from enhanced arrangements for dealing with machinery surveys. The arrangements provide the following advantages:

(a) A more flexible approach to dealing with Classification Surveys of machinery items. The condition as observed and reported by an LR approved Marine Engineer Officer will, subject to annual audit, be sufficient to credit the items for survey.
(b) A single system can be operated by the Navy covering maintenance, spare parts' supply and survey requirements.
(c) The schemes allow the application of condition monitoring techniques to main and auxiliary items of machinery.

15.1.4 When a Navy decides to apply such arrangements to limit the opening out normally required for survey under **CSM** then **MPMS, MCM** (including Condition Monitoring) or **RCM** (including Reliability Centred Maintenance) class notations can be assigned where the schemes have been approved by LR.

15.2 Master list items

15.2.1 A list of typical machinery master list items that can be surveyed by authorised personnel and those items that remain to be dealt with by LR Surveyors can be obtained from LR’s London Office. It should be noted that LR will continue to inspect, as necessary, where there is a history of mechanical, electrical or control engineering defects in a particular area, either on the ship or on a similar ship.

15.3 The planned maintenance approach

15.3.1 Types of maintenance are defined as:

(a) **Preventive maintenance.** This calls for items to be opened out for inspection and overhaul at specified time periods or after a specified number of running hours in order to keep the machine/equipment/system in a satisfactory operational condition.
(b) **Condition based maintenance.** This is dictated by the performance or physical state of the machine/equipment/ system, determined by regular or continuous checks of applicable parameters. Maintenance is only undertaken when conditions have approached or reached the lowest acceptable standard and before breakdown or failure occurs.
(c) **Reliability centred maintenance.** This calls for a structured analysis of a system's capability to perform its functions from design through operation to decommissioning. The primary objective is to ensure the functionality of a system and this is achieved through a planned maintenance strategy determined from the detailed analysis. The strategy may include the use of prevention and condition based maintenance.

15.3.2 The types of maintenance described in *Vol 1, Pt 1, Ch 3, 15.3 The planned maintenance approach 15.3.1* are the foundations of a Machinery Planned Maintenence System acceptable to LR. Many schemes are made up with a combination of the three methods of control. In addition, to deal with unforeseen circumstances, any Machinery Planned Maintenence System must also be able to deal effectively with breakdown or corrective maintenance, i.e. unscheduled maintenance.

15.4 Basic requirements for approval of MPMS, MCM and RCM schemes

15.4.1 To obtain approval of a **MPMS**, the Navy is required to make a formal request through either a local office of LR or direct to LR in London. The request is to be accompanied by the following information:

(a) A numbered index of the items to be included in the scheme. This index is to include at least all **CSM** items that appear on the Master List of Surveyable Items. The scheme can also cover many items that are not required for classification. The indexing system is to be such that ready cross-reference to the numbers in the LR Master List of Surveyable items can be made. It is also to indicate those items to be dealt with by preventive maintenance, by condition-based maintenance and by reliability centred maintenance.
(b) The maintenance and monitoring methods to be used, the time schedules for each item and limits of acceptance/ condition where applicable. Maintenance descriptions are to cover at least the minimum opening out necessary to demonstrate that a satisfactory examination of the item will be made. The extent of the work to be undertaken is to be indicated but it is not necessary for approval purposes to include every detailed job description. A few sample job descriptions will suffice to demonstrate how the system works. Machinery on preventive maintenance must be examined completely for survey purposes at intervals not exceeding six years, although in practice many items will be maintained much more frequently.
(c) A system for reporting to the Navy and recording on board ship and at the Navy's headquarters, details of maintenance carried out, the condition as found and any repairs effected, together with a list of spare parts used. The reporting and recording procedures are to be sufficiently comprehensive to demonstrate that both the Navy and the LR Surveyor can verify correct operation of the planned maintenance system at the time of the survey.
(d) A description of the scheme regarding its application on board ship and the proposed flow of maintenance documents and method of filing same. The application of the scheme may take the form of simple planning charts or the more complex interactive computer based systems. The language of the **MPMS** is to be English.

15.4.2 Where a Navy has requested approval of a Reliability Centred Maintenance study, the requirements of *Vol 1, Pt 1, Ch 3, 15.4 Basic requirements for approval of MPMS, MCM and RCM schemes 15.4.3* are to be complied with.

15.4.3 The following information is to be submitted to LR for review:

(a) Hard or soft copy (with operating systems if necessary) of the studies, conducted in accordance with a relevant national or international Standard, such as ISO 17359, *Condition monitoring and diagnostics of machines – General guidelines*. This is to include, operating context, details of study team, Risk Assessment (RA, *see also Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*), algorithm decision sheets, summary of maintenance tasks, summary of 'level of repair analysis', identification of 'critical' spares.
(b) Details of system/equipment covered by the study.
(c) Confirmation that maintenance studies have included where possible, OEM data on failure rates, OEM maintenance recommendations, and associated information necessary to ensure that risk associated with component failure is accounted for accurately.

15.4.4 LR will verify by audit that the following items have been complied with:

(a) Study has been undertaken in full compliance of the methodology embodied in an acceptable and applicable standard for **RCM**.
(b) Study team members have adequate experience both of undertaking **RCM** studies and the systems/equipment under review.
(c) Study team members have been present during the study for sufficient time (percentage of total time taken) to contribute properly to the study.
(d) No 'Mandatory Redesign' requirements are outstanding.
(e) Where spares have been identified as 'Critical', they have been properly identified in the management systems on board.
(f) Procedures for collection of condition monitoring information have been established and reporting procedures for submission of this as part of the approved **MPMS** are clearly documented.
(g) Where Standard Operating Procedures have been identified, that an adequate management system is in place to ensure that they are complied with.
(h) The **RA**, *see Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*, is in compliance with an acceptable standard, good marine engineering practice and application of valid reliability data.

15.4.5 A technical audit by LR of individual RCM studies selected by LR will follow the following methodology:

(a) Verification that the study covers the entire function being addressed.
(b) For each individual study (sub function) within a group function, verification that there is a list that includes the individual assets items, including controls, instrumentation and protective/ emergency devices.
(c) Verification that an expected maintenance task list has been drafted, based on typical tasks that would be expected for the relevant item, under any maintenance regime. These would include, but may not be limited to, system performance analysis checks, standard condition monitoring checks (vibration, electrical characteristics, thermography, etc), inspections of items liable to wear or other age related degradation, i.e. fouling, periodic tests of protective devices, operation of reversionary modes of operation, etc.
(d) Confirm that the standard tasks have been identified for each sub function.
(e) Review the study for justification for items or systems with no scheduled maintenance for tasks not identified.
(f) Review any inconsistencies in periodicity for tasks included in maintenance schedule.
(g) Carry out a review of **RCM** logic applied for one sub function. If the review is acceptable and in accordance with the standard for RCM, others will not be fully reviewed. If considered unacceptable, a review of another will be carried out for confirmation. If second also unacceptable, LR will require a complete review of all other sub functions for acceptance.
(h) Review LR Master List Surveyable items to verify that all Class items have a maintenance programme associated with credit as part of **RCM**.

15.4.6 As an alternative to LR carrying out post study audits required by *Vol 1, Pt 1, Ch 3, 15.4 Basic requirements for approval of MPMS, MCM and RCM schemes 15.4.4* and *Vol 1, Pt 1, Ch 3, 15.4 Basic requirements for approval of MPMS, MCM and RCM schemes 15.4.5*, LR can, if requested, provide direct input and advice to the study team(s) on either a full or part time basis to supplement the technical/survey requirement input. If this is undertaken, the scope of the audit will be reduced accordingly.

15.4.7 Where machinery items are maintained on a condition basis the following additional information is required to be submitted:

(a) A description of the applicable monitoring techniques and monitoring equipment to be used.

(b) A statement as to the acceptable limits of deteriorated condition. These should be derived from the manufacturer's recommendations, applicable severity criteria as defined in recognised Standards, or the Navy's required limits when these are more severe. Rotating machinery on condition based maintenance may be accepted for survey on the basis of the monitored readings without opening out if the condition is shown to be good.

15.4.8 If the planned maintenance scheme is considered to be acceptable to LR a 'Certificate for Operation of an Approved Planned Maintenance Scheme' will be issued. The Certificate is to be retained on board the subject ship for the information of the Commanding Officer, Marine Engineer Officer and LR's Surveyors.

15.4.9 The Marine Engineer Officer operating the Scheme on a ship must hold a valid LR Certificate of Authorisation.

15.5 Conditions of operation

15.5.1 It is a condition of the Scheme that the Navy arranges for LR Surveyors to carry out an Annual audit of the machinery maintenance and monitoring records. Annual audits are to be held within three months before or after the due date and it is recommended that they are harmonised with the ship's Annual Survey.

15.5.2 Marine Engineer Officers may carry out surveys of all the machinery items for which they are authorised, at sea or in port, whichever is the most convenient. The following machinery items remain to be dealt with by an LR Surveyor, unless special arrangements have been agreed with the Navy:

- Machinery damage, repairs and alterations, *see Vol 1, Pt 1, Ch 3, 15.6 Breakdown or corrective maintenance*
- Gas turbines for propulsion and electrical supplies.
- Oil engines for propulsion and electrical supplies.
- Steam turbines and boilers for propulsion and electrical supplies.
- Control, alarm and safety devices associated with the above main and auxiliary machinery.
- Reduction/increase gearing, flexible couplings and clutches.
- Holding down bolts and chocks.
- Steam pipes and valves on ships with steam turbine installations.
- Air receivers and other pressure vessels.
- Starting air pipes.
- Steering machinery.
- Pumping arrangements for bilge and dewatering systems.
- Electrical equipment other than auxiliary motors.
- Screwshafts, stern bearings and propellers.
- Sea connections.
- Machinery controls and controls associated with Class Notations, e.g. **UMS**, **CCS**, **ICC** and **IP**.
- Engine Trial.
- First start arrangement trial.

15.5.3 The confirmatory survey carried out at the time of the annual audit by LR's Surveyor will comprise of checks of the condition monitoring records and, if considered necessary, an examination of selected main and auxiliary machinery under working conditions.

15.6 Breakdown or corrective maintenance

15.6.1 LR is required to be notified when a breakdown or defect occurs and has a major effect that affects the Provisions of Classification and repairs are necessary. A major effect is an effect that produces:

(a) a significant increase in the operational duties of the crew or in their difficulty in performing their duties which by itself should not be outside the capability of a competent crew provided that another major effect does not occur at the same time; or

(b) significant degradation in the operational capability of the ship; or

(c) significant modification of the permissible operating conditions, but will not remove the capability to complete a safe journey without demanding more than normal skill on the part of the operating crew.

15.6.2 In discussion with the Navy and the Marine Engineer Officer, LR will advise what repairs and/or renewals are necessary for classification purposes, with the issue of an Interim Certificate of Class.

15.6.3 The required repair and time scale for completion will be the subject of discussion and agreement with LR and the Navy. It is the responsibility of the Navy to decide whether the ship's mission/operational tasking is more important than completing the repairs within the agreed time. It is accepted that such circumstances are occasionally inevitable, and LR would provide advice on the interim measures that could be introduced until such time as the required repairs are carried out and the implications on a ship's operating capability of delays in effecting repairs.

15.7 Annual audit and survey

15.7.1 At the annual audit the Marine Engineer Officer is required to make available the maintenance and monitoring records. These records may be in a hard or soft format and should include:

(a) Appropriate records of machinery or equipment surveyed under the supervision of the Marine Engineer Officer that are listed in the Master List of Surveyable Items. These statements should give details of repairs carried out and spare parts used.
(b) Written details of any breakdown or malfunction of essential machinery. Such details should include the main cause of failure.

These records will be examined in sufficient depth by the LR Surveyors to ensure that the scheme has been correctly operated and that the machinery has functioned satisfactorily since the previous survey. The records should indicate that all scheduled maintenance has been carried out. Any items not dealt with as per schedule will be discussed with the Marine Engineer Officer.

15.7.2 Where condition monitoring of main or auxiliary machinery is incorporated in the PMS the LR Surveyor will examine the records to verify that vibration levels, performance criteria, etc. are within the approved specified limits. The LR Surveyor may require confirmatory readings on available running machinery to be taken for comparison with the ship's records.

15.7.3 As part of the audit, LR Surveyors carry out a general examination of the machinery. As far as is practicable machinery to be credited for survey will be examined under working conditions. If the LR Surveyor is not satisfied with the condition as found he might require to have any items opened out for inspection.

15.7.4 The dates of items to be credited for Class will be aligned to the date of the confirmatory survey regardless of when the Marine Engineer Officer carried out his survey. Any other surveyable items of machinery not covered by the Scheme will be surveyed and credited in the normal way.

15.7.5 For items which the Marine Engineer Officer is authorised to survey and become due for survey between Annual Audits these will be shown as ‘OVERDUE' on the survey status until the Annual Audit has been held and reported.

15.7.6 In the event of the Surveyor not being satisfied that the planned maintenance scheme is being correctly followed, either from the maintenance records or from the general condition of the machinery, a report will be forwarded to LR recommending that the special arrangements for dealing with machinery surveys be suspended.

■ *Section 16*
Classification of ships not built under LR survey

16.1 General

16.1.1 When classification is desired for a ship not built under the supervision of LR Surveyors, application should be made in writing.

16.1.2 Periodical Surveys of such ships, when classed, are subsequently to be held as in the case of ships built under survey.

16.1.3 Where classification is desired for a ship which has not been designed, constructed and maintained to appropriate standards recognised by the Naval Authority, special consideration will be given to the requirements of this Section.

16.1.4 Where classification is desired for a ship which is classed by another recognised Society, special consideration will be given to the requirements of this Section.

16.2 Hull and equipment

16.2.1 Plans showing the main scantlings, corrosion margins and arrangements of the actual ship together with any proposed alterations are to be submitted. As a minimum the plans are to comprise a midship section, longitudinal section and decks. LR may request further plans. Documents demonstrating compliance with appropriate standards recognised by the Naval Authority are to be submitted. In the absence of such documentation, an appraisal may be required to the satisfaction of LR. For vessels which have generated sufficient evidence of satisfactory in-service experience LR may consider this in lieu of compliance

documentation or an appraisal. If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the ship.

16.2.2 Particulars of the process of manufacture and the testing of the material of construction are to be supplied. The requirements for composite ships will be specially considered.

16.2.3 The full requirements of *Vol 1, Pt 1, Ch 3, 5 Special Survey – Hull requirements*and *Vol 1, Pt 1, Ch 3, 6 Special Survey – Thickness measurement requirements for steel ships*are to be carried out as applicable. Ships of recent construction will receive special consideration.

16.2.4 During the survey, the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements. For this purpose, and also in order to ascertain the amount of any deterioration of a steel ship, parts of the structure will require to be gauged as necessary. Full particulars of the anchors, chain cables and equipment are to be submitted.

16.2.5 When the full survey requirements indicated in *Vol 1, Pt 1, Ch 3, 16.2 Hull and equipment 16.2.3* and *Vol 1, Pt 1, Ch 3, 16.2 Hull and equipment 16.2.4* cannot be completed at one time, LR may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merit of each particular case, which should be submitted for consideration.

16.3 Machinery

16.3.1 Plans of the following items (plans of piping are to be diagrammatic), together with the particulars of the materials used in the construction of the boilers, air receivers and important forgings are to be submitted. Documents demonstrating compliance with appropriate Standards recognised by the Naval Authority are to be submitted. In the absence of such documentation, an appraisal may be required to the satisfaction of LR. For vessels which have generated sufficient evidence of satisfactory in-service experience LR may consider this in lieu of compliance documentation or an appraisal:

General piping system arrangements, including air and sounding pipes (Builder's plan).
Bilge, dewatering, ballast and fuel oil piping arrangements including the capacities of the pumps on bilge service.
Arrangement and dimensions of main steam pipes.
Arrangement of fuel oil pipes and fittings at settling and service tanks.
Arrangement of fuel oil piping in connection with oil burning installations.
fuel oil overflow systems, where these are fitted.
Arrangement of boiler feed systems.
fuel oil settling, service and other fuel oil tanks not forming part of the ship's structure.
Boilers, superheaters and economisers.
Air receivers.
Crank, thrust, intermediate and screw shafting.
Clutch and reversing gear with methods of control.
Reduction gearing.
Propeller (including spare propeller if supplied).
Electrical circuits, as listed in *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.4*, *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.6* and *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.7*.
Arrangement of compressed air systems for main and auxiliary services.
Arrangement of lubricating oil, hydraulic oil, thermal oil and other systems containing flammable liquids.
Arrangements of cooling water systems for main and auxiliary services.
Steering gear system and piping arrangements together with manufacturer, model and rating information.
Aircraft/helicopter and vehicle fuel storage and distribution systems.
Chilled water systems.
High pressure sea-water systems.
Heating and ventilation systems.
Made and fresh water systems.
Hydraulic power actuating systems.
Propulsion engine details including manufacturer, model and rating information.
Electrical generator engine details including manufacturer, model and rating information.

For **UMS** notation the following plans are to be submitted for appraisal:

- Fire alarm system.
- Instrumentation list.
- Plans for systematic maintenance and function testing.
- Test schedule.

Where an Ice Class notation is required the following plans are to be submitted for appraisal:

- Main propulsion line shafting.
- Reduction gears.
- Propeller.
- Details of any clutch system in the propulsion line.

Replenishment at sea arrangements where a **RAS** notation is requested.

16.3.2 Plans additional to those detailed in *Vol 1, Pt 1, Ch 3, 16.3 Machinery 16.3.1* are not to be submitted unless the machinery is of a novel or special character affecting classification.

16.3.3 Where remote and/or automatic controls are fitted to propulsion machinery and essential auxiliaries, a description of the scheme is to be submitted.

16.3.4 For new ships and ships which have been in service less than two years, calculations of the torsional vibration characteristics of the propelling machinery are to be submitted for consideration, as required for ships constructed under Special Survey. For older ships the circumstances will be specially considered in relation to their service record and type of machinery installed. Where calculations are not submitted, LR may require that the machinery certificate be endorsed to this effect. When desired by the Owner, the calculations and investigation of the torsional vibration characteristics of the machinery may be carried out by LR upon special request.

16.3.5 The main and auxiliary machinery, feed pipes, compressed air pipes and boilers are to be examined as required at Complete Surveys. Working pressures are to be determined from the actual scantlings in accordance with the Rules.

16.3.6 The screwshaft is to be drawn and examined.

16.3.7 The steam pipes are to be examined and tested as required by *Vol 1, Pt 1, Ch 3, 12 Steam pipes*

16.3.8 The bilge, dewatering, ballast and fuel oil pumping arrangements are to be examined and amended, as necessary, to comply with the Rules.

16.3.9 Oil burning installations are to be examined as required at Complete Surveys and found, or modified, to comply with the requirements of the Rules; they are also to be tested under working conditions.

16.3.10 The electrical equipment is to be examined as required at Complete Surveys.

16.3.11 The whole of the machinery, including essential controls, is to be tested under working conditions to the Surveyor's satisfaction.

16.3.12 Relevant reports are to be prepared by the Surveyors.

■ *Section 17*
Classification of ships built under survey to LR Classification Rules and Regulations other than LR Naval Ship Rules and Regulations

17.1 General

17.1.1 When Naval ship classification is desired for an existing ship built under the supervision of LR Surveyors to Classification Rules and Regulations other than LR Naval Ship Rules, application should be made in writing.

17.1.2 Periodical Surveys of such ships, when classed to the LR Naval Ship Rules are subsequently to be held as in the case of ships built under survey to the Naval Ship Rules. All features of the extant survey regime for hull and machinery are to be included in the Survey scheme under the Naval Ship Rules.

17.2 Hull and equipment

17.2.1 Plans showing the features of the ship not covered by the other Classification Rules against which the ship is classed are to be submitted. These may include the following items. For these items, documents demonstrating compliance with appropriate Standards recognised by the Naval Authority are to be submitted. In the absence of such documentation, an appraisal may be required to the satisfaction of LR. For vessels which have generated sufficient evidence of satisfactory in-service experience LR may consider this in lieu of compliance documentation or an appraisal. Where an appraisal is undertaken, strength and, where appropriate, stiffness aspects are to be addressed:

- Masts.
- Weapon system seats.
- RAS seats, landing areas.
- Aircraft landing guides.
- Towing points.
- Military loads.
- Beaching.
- Material grades.
- Watertight integrity.
- Strength of watertight structure.

If plans cannot be obtained or prepared by the Owner, facilities are to be given for LR's Surveyor to obtain the necessary information from the ship.

17.2.2 Suitable documentation should be presented to demonstrate that the following aspects are addressed by the appropriate Naval Authority:

- Stability.
- Magazine safety.
- Lifts, ramps, shell doors.
- Fire safety.

17.2.3 During the survey, the Surveyors are to satisfy themselves regarding the workmanship and verify the approved scantlings and arrangements of additional features covered by the Rules. For this purpose, and also in order to ascertain the amount of any deterioration of a steel ship, parts of the structure may need to be gauged as necessary.

17.2.4 When the full survey requirements indicated in *Vol 1, Pt 1, Ch 3, 7.2 Complete Survey 7.2.4* cannot be completed at one time, LR may consider granting an interim record for a limited period. The conditions regarding the completion of the survey will depend on the merit of each particular case, which should be submitted for consideration.

17.3 Machinery

17.3.1 Plans of systems not covered by the other Classification Rules against which the ship is classed are to be submitted to LR. For these systems, documents demonstrating compliance with appropriate Standards recognised by the Naval Authority are to be submitted. In the absence of such documentation, an appraisal may be required to the satisfaction of LR. For vessels which have generated sufficient evidence of satisfactory in-service experience LR may consider this in lieu of compliance documentation or an appraisal:

(a) Aircraft/helicopter and vehicle fuel storage and distribution systems.
(b) Chilled water systems.
(c) High pressure sea-water systems.
(d) High and low pressure compressed air systems.
(e) Hydraulic power actuating systems.
(f) Made and fresh water systems.
(g) Heating, ventilation and cooling arrangements.
(h) Replenishment at sea arrangements where a **RAS** notation is requested.

17.3.2 Details additional to those detailed in *Vol 1, Pt 1, Ch 3, 17.3 Machinery 17.3.1* are not to be submitted unless the machinery or installation is of a novel or special character affecting Mobility, Ship Type or Ancillary category systems for Machinery Naval Classification.

17.3.3 The whole of the machinery, including essential controls and safety arrangements, is to be tested to an agreed test plan under working conditions to the Surveyor's satisfaction.

17.3.4 Relevant reports on the submitted information and testing are to be prepared by the Surveyors.

Section 1
Rules for the Manufacture Testing and Certification of Materials

1.1 Reference

Please see *Rules for the Manufacture, Testing and Certification of Materials, July 2015*

■ Section 1
Rules application

1.1 General

1.1.1 The Rules apply in general to ships of normal form, proportions and speed. Although the Rules are, in general, for steel ships of all welded construction, other materials for use in the construction will be considered.

1.2 Exceptions

1.2.1 Ships of unusual form, proportions or speed, or for special or restricted service, or purposes not covered specifically by the Rules, will receive individual consideration based on the general standards of the Rules.

1.3 Loading

1.3.1 The Rules are framed on the understanding that ships will be properly handled. The Committee may require additional strengthening to be fitted in any ship which, in their opinion, would otherwise be subjected to severe stresses due to particular features of the design, or where it is desired to make provision for exceptional load or ballast conditions.

1.4 Advisory services

1.4.1 The Rules do not cover certain technical characteristics, such as stability except as mentioned in *Vol 1, Pt 1, Ch 2, 1.1 Framework of Classification 1.1.8*, trim, vibration (other than local panel) and docking arrangements, etc. The Committee cannot assume responsibility for these matters but is willing to advise upon them on request.

1.5 Interpretation

1.5.1 The interpretation of the Rules is the sole responsibility and at the sole discretion of Lloyd's Register (hereinafter referred to as 'LR'). Where there is any doubt regarding the interpretation of the Rules it is the designers' responsibility to obtain clarification from LR prior to submission of plans and data for appraisal. Similarly, where there is any doubt regarding the interpretation of the Owners' requirements it is the designers' responsibility to obtain clarification from the Owners prior to the submission of plans.

1.5.2 Attention is drawn to the fact that Codes of Practice issued by IMO contain requirements which are outside classification as defined in these Rules. Whilst they may not be mandatory for naval ships they will be adopted when specified.

1.6 Aesthetics

1.6.1 LR is not concerned with the general arrangement, layout and appearance of the ship; the responsibility for such matters remains with the Builders and/or designers to ensure that the agreed specification is complied with. LR is however concerned with the quality of workmanship, in this respect the acceptance criteria as required by Rules, LR Survey Procedures or equivalent are to be complied with.

1.7 Constructional configuration

1.7.1 The Rules provide for a basic structural configuration of a multi-deck or a single deck hull which includes a double bottom, or a single bottom arrangement. The structural configuration may also include a single or multiple arrangement of deck openings, and tanks.

■ *Section 2* Direct calculations

2.1 General

2.1.1 Direct calculations may be specifically required by the Rules or may be required for ships having novel design features, as defined in *Vol 1, Pt 3, Ch 1, 1.2 Exceptions*, or may be submitted in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of designers and make recommendations in regard to suitability of any required model tests.

2.1.2 Where model testing is undertaken to complement direct calculations the following details would normally be required to be submitted: schedule of tests, details of test equipment, input data, analysis and calibration procedure together with tabulated and plotted output.

2.2 Submission of direct calculations

2.2.1 In cases where direct calculations have been carried out, the following supporting information should be submitted as applicable:

(a) Reference to the direct calculation procedure and technical program used.
(b) A description of the structural modelling.
(c) A summary of analysis parameters including properties and boundary conditions.
(d) Details of the loading conditions and the means of applying loads.
(e) A comprehensive summary of calculation results. Sample calculations should be submitted where appropriate.

2.2.2 In general, submission of large volumes of input and output data associated with such programs as finite element analysis will not be necessary.

2.2.3 The responsibility for error free specification and input of program data and the subsequent correct transposition of output rests with the designer.

■ *Section 3* Equivalents

3.1 Alternative arrangements and calculation methods

3.1.1 In addition to cases where direct calculations are specifically required by the Rules, LR will consider alternative scantlings which have been derived by direct calculations in lieu of specific Rule requirements. All direct calculations are to be submitted for examination.

3.1.2 Where calculation procedures are employed, supporting documentation is to be submitted for appraisal and this is to include details of the following:

- calculation methods;
- assumptions and references;
- loading;
- structural modelling;
- design criteria and their derivation, e.g. permissible stresses, factors of safety against plate panel instability, etc.

3.1.3 LR will be ready to consider the use of Builder's programs for direct calculations in the following cases:

(a) Where it can be established that the program has previously been satisfactorily used to perform a direct calculation similar to that now submitted.

(b) Where sufficient information and evidence of satisfactory performance is submitted to substantiate the validity of the computation performed by the program.

3.1.4 Alternative arrangements or fittings which are considered to be equivalent to the Rule requirements will be accepted, in accordance with *Vol 1, Pt 1, Ch 2, 3.2 Tailoring – Departures from the Rules and Rule additions*.

3.1.5 Where no special reference is made in this Part to specific requirements, the construction is to be efficient for the intended purpose and to conform to good practice.

3.1.6 Where items are of a novel or unconventional design or manufacture, it is the responsibility of the designer to demonstrate their suitability and equivalence to the Rule requirements.

■ *Section 4* Information required

4.1 Submission of plans and data

4.1.1 Plans and data required to be submitted are indicated in *Vol 1, Pt 6, Ch 1, 2.2 Plans to be submitted*

4.1.2 Plans are generally to be submitted in triplicate, but one copy only is necessary for supporting documents and calculations.

4.1.3 Plans are to contain all necessary information to fully define the structure, including construction details, equipment and systems as appropriate.

4.2 Standard designs

4.2.1 Where a ship is a standard design produced in several versions, the plans and data are to clearly define the differences between each version.

4.2.2 Where the ship is a Builder's standard design to be built from previously approved plans and data, a schedule of applicable plans, etc. is to accompany the Request for Survey. Plans of any proposed modifications and changes to the previously approved plans are to be submitted for approval prior to the commencement of any work.

4.2.3 Plan approval of standard designs is only valid so long as no applicable Rule changes take place. When the Rules are amended, the plans for standard types are to be submitted for re-approval.

4.3 Plans and data to be supplied to the ship

4.3.1 A copy of the final Loading Manual or stability information book, (where applicable) when approved, and details of the loadings applicable to approved decks, are to be placed on board the ship.

4.3.2 Copies of all main scantling plans are to be readily available on board ship for the purposes of repairs, identifying materials and condition assessment.

4.3.3 Details of any corrosion control system fitted are to be placed on board the ship.

4.3.4 Where in-water surveys are required, approved plans and information covering the items detailed in *Vol 1, Pt 6, Ch 1, 2.2 Plans to be submitted* are to be placed on board.

■ *Section 5* Definitions

5.1 General

5.1.1 The following definitions apply except where they are inappropriate or where specifically defined otherwise.

5.2 Principal particulars

5.2.1 **Length waterline**, L_{WL}, is the distance, in metres, measured on a waterline at the design draught from the fore side of the stem to the after side of the stern or transom as shown in *Figure 1.5.1 Lengths*

5.2.2 **Rule length**, L_R, is the distance, in metres, on a waterline at the design draught from the forward side of the stem to the after side of the rudder post or to the centre of the rudder stock if there is no rudder post. L_R is to be not less than 96 per cent, and need not be greater than 97 per cent, of the extreme length on a waterline at the design draught. In vessels without rudders, the Rule length, L_R, is to be taken as 97 per cent of the extreme length on a waterline at the design draught. In vessels with unusual stem or stern arrangements, the Rule length will be specially considered.

5.2.3 All references to longitudinal locations in the Rules are to be taken as forward of the aft end of L_R unless otherwise stated, e.g. $0{,}75L_R$ is 75 per cent of L_R forward of the aft end of L_R.

5.2.4 **Length between perpendiculars**, L_{PP}, is the distance, in metres, on the waterline at the design draught from the forward to the after perpendicular.

5.2.5 **Forward perpendicular**, F.P., is the perpendicular at the intersection of the waterline at the design draught with the fore side of the stem.

5.2.6 **After perpendicular**, A.P., is the perpendicular at the intersection of the waterline at the design draught with the after side of the rudder post or to the centre of the rudder stock for vessels without a rudder post or to the intersection with the transom profile on the centreline.

5.2.7 **Length overall**, L_{OA} , is the distance, in metres, measured parallel to the deep load waterline from the fore side of the stem to the after side of the stern or transom, excluding rubbing strakes and other projections as shown in *Figure 1.5.1 Lengths*.

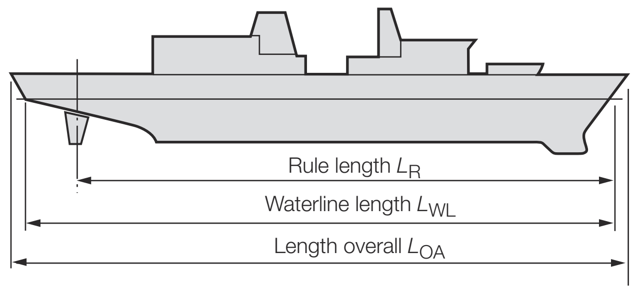


Figure 1.5.1 Lengths

5.2.8 **Waterline breadth**, B_{WL}, is generally the greatest moulded breadth, in metres, measured at the design draught, as shown in *Figure 1.5.2 Tranverse dimensions*.

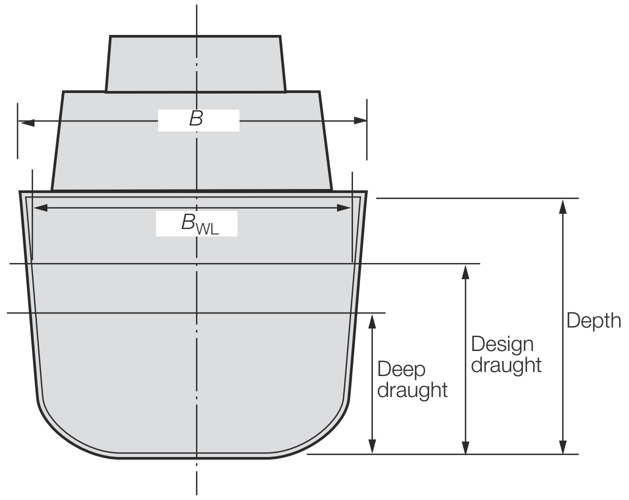


Figure 1.5.2 Tranverse dimensions

5.2.9 **Breadth**, *B*, is generally the greatest moulded breadth, in metres, throughout the depth of the ship or as defined in appropriate Chapters. For vessels of unusual cross-section the breadth will be specially considered.

5.2.10 **Depth,** *D*, is measured, in metres, at amidships, from top of keel plate to the moulded deck line at side on the uppermost continuous deck, or as defined in appropriate Chapters or standards. When a rounded gunwale is arranged, the depth *D* is to be measured to the continuation of the moulded deck line at side.

5.2.11 **Draught**, *T*, is the design draught, in metres, measured from moulded baseline.

5.2.12 **Block coefficient**, C_b , is the block coefficient at draught *T* corresponding to a waterline at the design draught, based on Rule length L_R and breadth B_{WL}, as follows:

$$C_b = \frac{\text{moulded displacement}\left(\text{m}^3\right)\text{ at draught }T}{L_R B_{WL} T}$$

5.2.13 Design draught may be determined from the waterline when the vessel is in a deep condition plus any specified margins. Where specified a higher waterline may be used.

5.2.14 Deep draught is measured at a displacement such that the ship is in all respects complete, and is fully loaded with full complement, stores, fuel, water and payload.

5.2.15 Payload is the equipment and stores that are carried by the vessel for the purposes of fulfilling its operational requirements.

5.3 Margins

5.3.1 Design margin is an allowance for uncertainties used in the estimation of weight for design purposes.

5.3.2 Build margin is an allowance for unforeseen changes that may need to be made by the builder of the vessel.

5.3.3 Admiralty board margin is an allowance to cater for modifications made by the Owner to the vessel or equipment during the design and build stages.

5.3.4 Growth margin is an allowance for future controlled and uncontrolled weight growth during the life of the ship.

5.3.5 In the absence of any specific requirements, the sum of the margins is be taken as 15 per cent of the displacement at the deep draught.

5.4 Decks

5.4.1 Strength deck is normally the uppermost continuous deck. Other decks may be considered as the strength deck provided that such decks are structurally effective. Where the upper deck is stepped, as in the case of vessels with a quarter deck, the strength deck is stepped, *see Vol 1, Pt 6, Ch 4, 1 General*.

5.4.2 The weather deck is generally the lowest continuous deck exposed to sea and weather loads. It is to be defined at the early stages of design in conjunction with LR and the Builder.

5.4.3 Other decks that are exposed to sea loads are to be assessed in accordance with the requirements for weather decks.

5.4.4 The damage control deck is the lowest deck on which continuous fore and aft access is provided to aid communications and recovery following damage. It is normally above the lowest vertical limit of watertight integrity, the exact location being determined by the relevant subdivision and watertight integrity standard.

5.5 Co-ordinate system

5.5.1 Unless otherwise stated, the co-ordinate system is as shown in *Figure 1.5.3 NSR Co-ordinate system*, that is, a right-hand co-ordinate system with the X axis positive forward, the Y axis positive to port and the Z axis positive upwards. Angular motions are considered positive in a clockwise direction about the X, Y or Z axes.

5.6 Superstructure

5.6.1 For the purposes of strength assessment a superstructure is defined as a decked structure on the strength deck, extending from side to side of the vessel, or with its side plating being less than four per cent of the breadth, *B*, inboard of the shell plating.

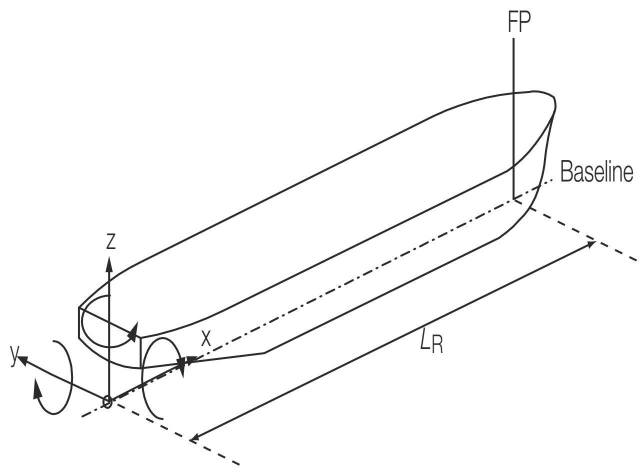


Figure 1.5.3 NSR Co-ordinate system

5.7 Deckhouse

5.7.1 A deckhouse is in general defined as a decked structure on or above the strength deck with its side plating being four per cent or more of the breadth, *B*, inboard of the shell plating.

5.8 Weathertight

5.8.1 A boundary or closing appliance is considered weathertight if it is capable of preventing the passage of water into the ship in any sea conditions.

5.9 Watertight

5.9.1 A boundary or closing appliance is considered watertight if it is capable of preventing the passage of water in either direction under a head of water for which the surrounding structure is designed.

5.10 Terminology

5.10.1 *Figure 1.5.4 Longitudinal framing system* shows the general terminology adopted for structural items for a transversely and longitudinally framed ship.

5.10.2 *Figure 1.5.6 NS1 Conventional aircraft carrier* shows the general configuration of Naval ships of the NS1 and NS2 types. Various features are pointed out and are dealt with by the relevant Section of the Rules.

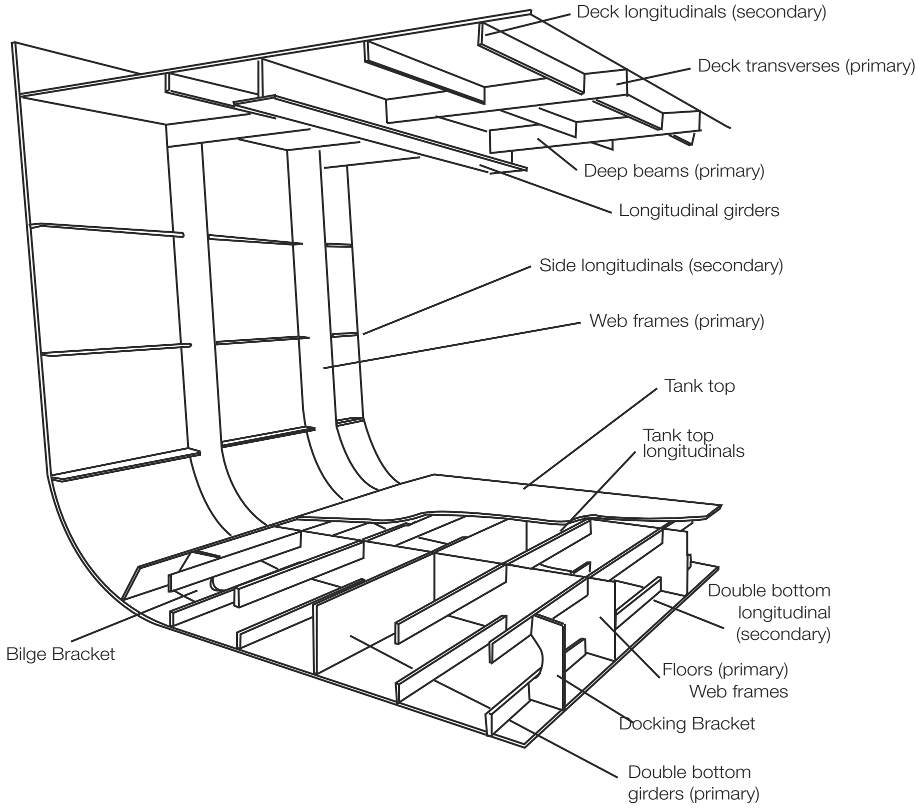


Figure 1.5.4 Longitudinal framing system

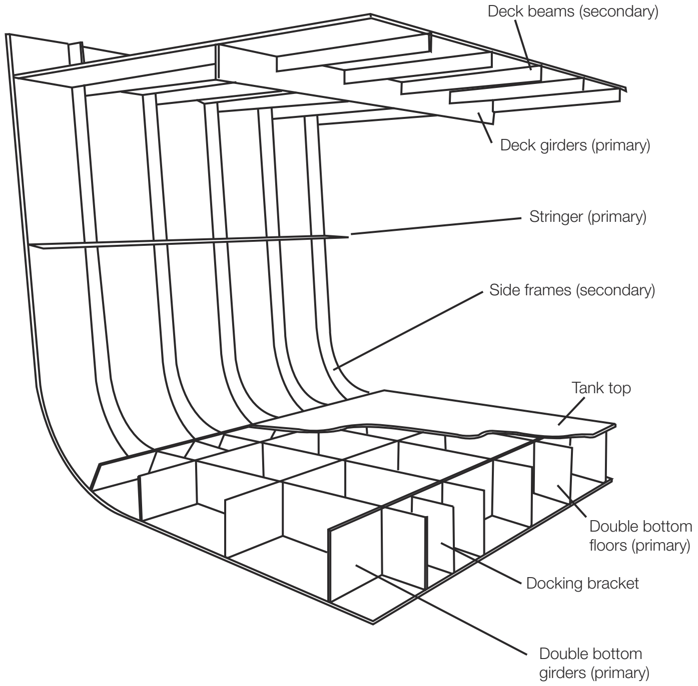


Figure 1.5.5 Transverse framing system

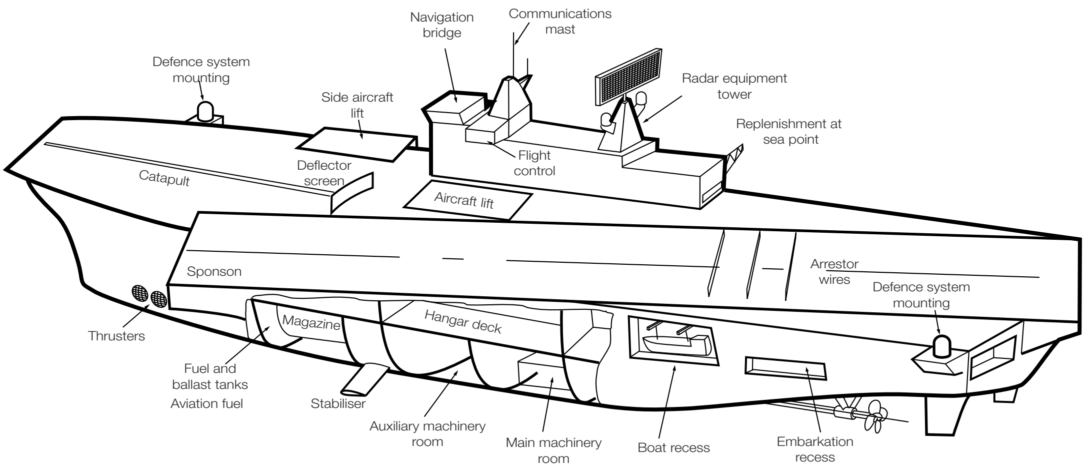


Figure 1.5.6 NS1 Conventional aircraft carrier

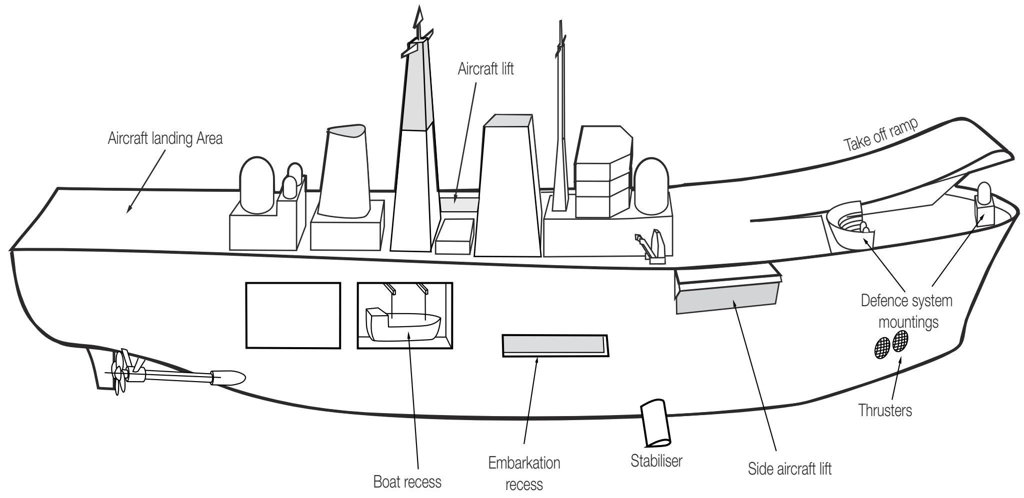


Figure 1.5.7 NS1 Short take off aircraft carrier

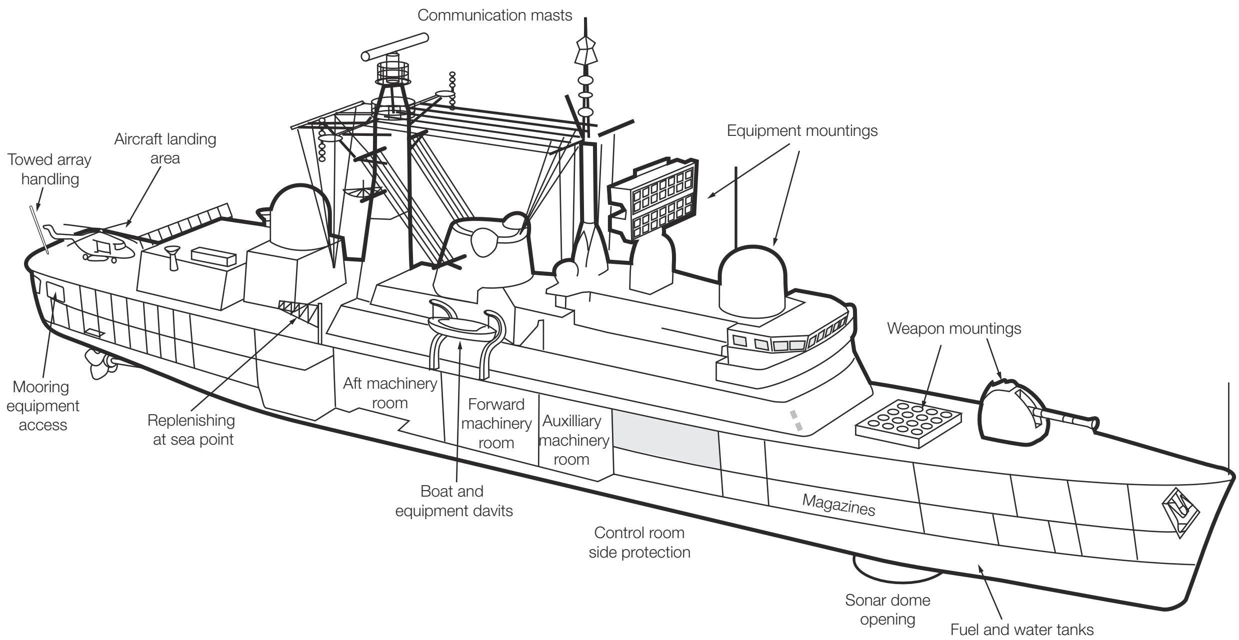


Figure 1.5.8 NS2 Frigate/Destroyer

5.11 Extent of watertight subdivision

5.11.1 The minimum extent of watertight subdivision (internal), and integrity (internal and external), is to be in accordance with the specified subdivision and stability standard(s).

5.11.2 The minimum extent of watertight subdivision may be defined by a combination of decks, side shell and bulkheads or by a single deck.

5.11.3 Weathertight and watertight fittings and closing appliances are to be fitted in accordance with the requirements of the boundary on which they are placed.

5.11.4 For the calculation of watertight structural scantlings the pressure head is to be taken from the vertical limits of weathertightness determined by either intact or damage stability considerations in accordance with the specified subdivision and stability standard(s), *see Vol 1, Pt 3, Ch 2, 1.3 Watertight and weathertight integrity* and *Vol 1, Pt 5, Ch 3, 5.5 Loads for deckhouses, bulwarks and superstructures, Pdh*

5.12 Critical compartments

5.12.1 A critical compartment is one which, at battle stations, contains equipment or personnel without whom functions critical to combat survivability would be lost. These functions include the ability to fight, manoeuvre or communicate.

5.12.2 Critical compartments are typically the chart room, operations room, conning position, ship's control room and main communications office. Other compartments may be considered critical depending on ship's layout and design. The need for protecting critical compartments can be reduced by avoiding single point failure nodes and by concentrating and protecting those which cannot be avoided. A vulnerability analysis can be used to identify vulnerable critical compartments and the essential pieces of equipment or systems that are required to be protected, *see Vol 1, Pt 3, Ch 1, 2.2 Submission of direct calculations*.

5.12.3 Critical pipe and cable runs are routes in which the connections for survivability critical components run. They can cover individual routes or concentrated areas. An example is a run containing wave guides and signal cables for all the above water sensors on the mast.

5.13 Units system

5.13.1 Unless otherwise stated, the variables used in the Rules are expressed in the following units.

5.13.2 **General**

Distances	m
Primary spacings	m
Secondary spacings	mm

5.13.3 **Hull girder properties**

Dimensions	m
Area	m^2
Section modulus	m^3
Inertia	m^4
Area-moment	m^3

5.13.4 **Stiffeners**

Area	cm^2
Dimensions	mm
Inertia	cm^4
Section modulus	cm^3
Length/length effective	m

5.13.5 **Plating**

Breadth	mm
Length	m
Thickness	mm

5.13.6 **Loads**

Pressures	kN/m^2
Loads	kN
Bending moment	kN-m
Shear force	kN

5.13.7 **Other items**

Yield strength	N/mm^2
Stress	N/mm^2
Deflections	mm
Modulus of Elasticity	N/mm^2

■ *Section 6* **Building tolerances and associated repairs**

6.1 Overview

6.1.1 The general tolerances for new building and subsequent repairs are to be in accordance with the requirements of the *Naval Survey Guidance for Steel Ships*, or an otherwise specified and agreed standard.

6.1.2 Tolerances to be used for constructional misalignment for all materials are to be discussed between Owners/Builders and the Surveyor and the Standards agreed subject to the requirements of *Vol 1, Pt 3, Ch 1, 6.1 Overview 6.1.1*. The permitted degree of inaccuracy/misalignment will vary according to whether the defect is:

(a) In primary structure.
(b) In secondary structure.
(c) Equipment supporting structure or underwater plate near acoustic equipment.
(d) Aesthetically pleasing

6.1.3 The requirements of these Rules are primarily concerned with ensuring items *Vol 1, Pt 3, Ch 1, 6.1 Overview 6.1.2* and *Vol 1, Pt 3, Ch 1, 6.1 Overview 6.1.2*. The equipment manufacturer will be able to give advice on the maximum noise or misalignment that can be tolerated from item *Vol 1, Pt 3, Ch 1, 6.1 Overview 6.1.2*. Aesthetics, item *Vol 1, Pt 3, Ch 1, 6.1 Overview 6.1.2*, are at the discretion of the Owner.

■ *Section 7* **Inspection and testing**

7.1 Overview

7.1.1 The general requirements for testing and inspection of structural items are to be in accordance with the requirements of *Vol 1, Pt 6, Ch 6, 6 Inspection and testing procedures* and LR's *Naval Survey Guidance for Steel Ships*.

7.1.2 Adequate facilities are to be provided to enable the Surveyor to carry out a satisfactory inspection and testing of all components during each stage of prefabrication and construction.

■ *Section 1*
General

1.1 Application

1.1.1 This Chapter illustrates the general principles to be adopted in the design of naval ships. Principles for subdivision and for maintaining watertight integrity are also covered.

1.1.2 Where additional requirements relating to particular ship types apply, these requirements are indicated in the appropriate Parts and are to be complied with as necessary.

1.1.3 These Rules are to be applied with reference to the operational conditions defined in the Concept of Operations, *see Vol 1, Pt 1, Ch 2, 2.2 Definitions*.

1.2 Definitions

1.2.1 The Down flooding angle is the least angle of heel at which openings in the hull, superstructure or deckhouses, which cannot be closed weathertight, immerse and allow flooding to occur.

1.2.2 The minimum required angle of down flooding, θ_{df}, is to be taken as 40° except when a higher minimum angle is required in accordance with the specified subdivision and stability standard(s), *see Vol 1, Pt 1, Ch 2, 1.1 Framework of Classification 1.1.9*

1.3 Watertight and weathertight integrity

1.3.1 The extents of the external and internal watertight and weathertight integrity are defined by the intact and damage stability requirements, *see Vol 1, Pt 1, Ch 2, 1.1 Framework of Classification 1.1.9*. From these extents, the design pressure heads for bulkheads and other boundaries can be derived as well as the closing arrangement requirements for openings. Weathertight and watertight integrity are defined in *Vol 1, Pt 3, Ch 1, 5 Definitions* and *see Vol 1, Pt 3, Ch 4 Closing Arrangements and Outfit* for the requirements for closing arrangements.

1.3.2 **Intact stability**

1.3.3 Intact stability calculations to satisfy the applicable criteria may be based on the buoyancy of the main hull, together with any superstructures that have watertight and weathertight boundaries, *see Figure 2.1.1* and *Figure 2.1.2* .

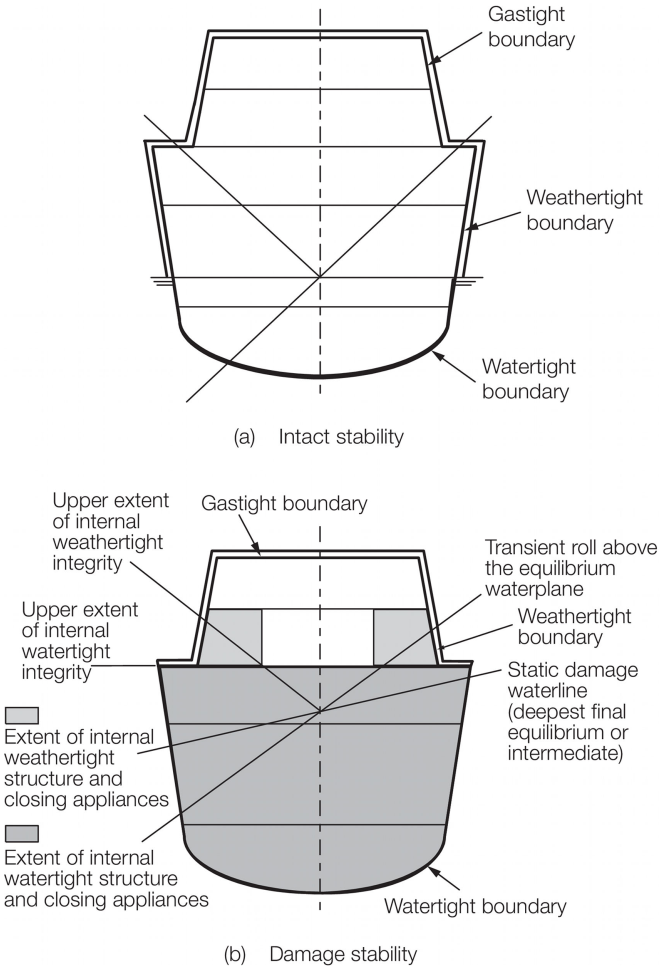

Gastight boundary
Weathertight boundary
Watertight boundary
(a) Intact stability
Upper extent of internal weathertight integrity
Gastight boundary
Transient roll above the equilibrium waterplane
Upper extent of internal watertight integrity
Weathertight boundary
Static damage waterline (deepest final equilibrium or intermediate)
Extent of internal weathertight structure and closing appliances
Extent of internal watertight structure and closing appliances
Watertight boundary
(b) Damage stability

Figure 2.1.1

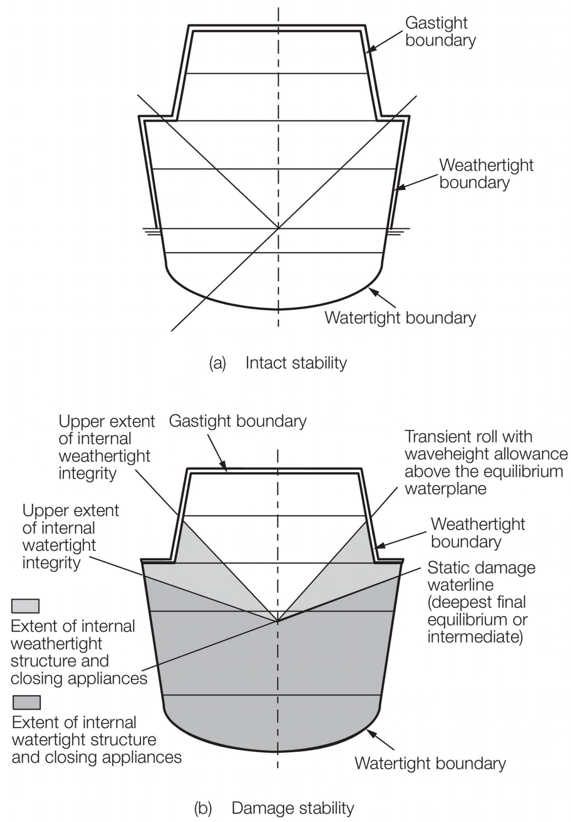


Figure 2.1.2

1.3.4 Doors, hatches, ventilators, windows, sidelights, etc. provided with closing appliances which can be secured weathertight, and small openings through which progressive flooding cannot take place are not considered as down flooding points.

1.3.5 If the angle of down flooding is less than θ_{df}, *see Vol 1, Pt 3, Ch 2, 1.2 Definitions 1.2.2*, with the ship at its design draught, it is necessary to establish whether there is sufficient area under the righting lever curve up to the angle of down flooding. If there is insufficient area, then the opening which is causing down flooding to occur is to be provided with a weathertight closing appliance, or be repositioned.

1.3.6 **Damage stability**

1.3.7 Typically there are two approaches to defining the limits of watertight and weathertight integrity:

(a) One where the watertight integrity is defined by the bulkhead or freeboard deck, in accordance with normal *SOLAS - International Convention for the Safety of Life at Sea* requirements.
(b) The other is based on watertight integrity up to a damaged stability draft and heel envelope, the latter is commonly used by Navies.

These two approaches are illustrated in *Figure 2.1.1* and *Figure 2.1.2* respectively.

1.3.8 *Figure 2.1.1* represents the *SOLAS - International Convention for the Safety of Life at Sea* style requirements.

- Below the limit of watertight integrity the boundary structure is to be watertight.
- Below the limit of weathertight integrity defined by the transient roll angle the boundary structure is to be weathertight, in order to prevent ingress of water into the enclosed volume considered buoyant in the stability calculations and prevent downflooding.
- Above the limit of weathertight integrity the boundary structure, or some other internal boundary, may need to be gas-tight for CBRN protection.

- Below the limit of watertight integrity defined by the top of the watertight bulkhead, the bulkhead is to be designed as watertight.
- Below the limit of weathertight integrity defined by the transient roll angle and above the limit of watertight integrity the internal structure is to be designed to prevent progressive flooding of water into other compartments.

1.3.9 *Figure 2.1.2* represents a standard based on damaged stability draft and heel envelope approach commonly used by Navies.

- Below the limit of watertight integrity the boundary structure is to be watertight.
- Below the limit of weathertight integrity defined by the transient roll angle the boundary structure is to be weathertight.
- Above the limit of weathertight integrity the boundary structure, or some other internal boundary, may need to be gastight for CBRN protection.
- Below the limit of watertight integrity defined by the locii of static damage waterlines the watertight bulkheads are to be designed as watertight.
- Below the limit of weathertight integrity defined by the transient roll angle and above the limit of watertight integrity the internal structure is to be weathertight in order to prevent progressive flooding of water into other compartments.

1.3.10 In the absence of specific information on the vertical limit of watertight integrity, the upper extent of the watertight boundary may be assumed with the apex of the triangle on the damage control deck at the location under consideration, *see Figure 2.1.2* and *Vol 1, Pt 3, Ch 1, 5.4 Decks 5.4.4*.

1.4 Structural redundancy

1.4.1 The role and duty of a naval ship dictates that a certain degree of structural redundancy should be incorporated in the design. It is recommended that, as a minimum standard, a basic level of structural redundancy is included where practicable. This is normally achieved by considering likely damage scenarios, identifying the effects on structure, assessing the new loads and ensuring that the remaining structure will be satisfactory.

1.4.2 These Rules will not automatically ensure that a ship has structural redundancy. It is the responsibility of the designer to consider and design for the possible loads on a structure from damage scenarios. The **RSA** notation can be used to define residual strength requirements.

1.4.3 At a very basic level structural redundancy can be achieved by considering the removal of appropriate items of structure and re-evaluating the strength of remaining members using the loads presented in these Rules. Alternatively, the overall structural redundancy can be formally assessed and a notation assigned using the residual strength analysis detailed in *Vol 1, Pt 3, Ch 2, 1.5 Residual Strength Assessment, RSA*.

1.5 Residual Strength Assessment, RSA

1.5.1 The design of a naval ship necessitates the reliable evaluation of its structural vulnerability to ensure the existence of adequate residual strength in the event of structural damage following a contact/collision incident or as a result of wartime activities. This strength assessment is additional to that required to cope with the design bending moments derived from environmental sea-state loading. The **RSA** notation within the Rules may be used to formally assess the overall structural redundancy.

1.5.2 The Owner may specify that a residual strength assessment is not required. In this case, the residual strength notation and all other notations which require the residual strength notation will not be assigned.

1.5.3 The capability to survive is to be judged on the residual structural strength after damage being able to meet specified global strength requirements and also local strength requirements in the event of damage leading to flooding, *see Vol 1, Pt 6, Ch 4, 4 Residual Strength Assessment, RSA*.

1.5.4 A residual strength assessment performed as defined in the Rules assumes that a ship can remain operational for a limited period of time in reduced sea states, *see Vol 1, Pt 6, Ch 4, 1.2 Hull girder strength notations*. Where a higher operational capability following damage is specified, special consideration will need to be given and revised criteria set.

1.5.5 The Owner may specify an alternative mission statement, in which case the requirements of the residual strength assessment procedure will be modified.

1.5.6 The residual strength assessment as defined in the Rules considers three main definitions of damage:

- Peacetime damage extents, *see Vol 1, Pt 6, Ch 4, 2 Hull girder strength*.
- Military threats, *see Vol 1, Pt 4, Ch 2, 7 Residual strength*

- As defined by the Owner.

1.5.7 The environmental parameters for the residual strength assessment procedure are given in*Vol 1, Pt 5, Ch 2 Environmental Conditions*. The local and global loads for use in the **RSA** assessment procedure are given in *Vol 1, Pt 5, Ch 3, 5 Local design loads for decks and bulkheads* and *Vol 1, Pt 5, Ch 4, 5 Residual strength hull girder loads* respectively.

1.5.8 **RSA** notation assessment levels are given in *Vol 1, Pt 4, Ch 2, 7 Residual strength*. The acceptance criteria and procedures to be adopted for the application of the residual strength notation are given in *Vol 1, Pt 6, Ch 4, 4 Residual Strength Assessment, RSA*. *See also Vol 1, Pt 1, Ch 2, 3.6 Service area notations 3.6.1*.

1.5.9 Further guidance for undertaking residual strength analysis for the determination of a residual strength notation is given in LR's Naval Ship Guidance Notes.

■ *Section 2*
Rule structural concept

2.1 General

2.1.1 The Rules are based on the concept that the structural and watertight integrity and general safe operation of the ship will not be compromised by static and dynamic loads experienced during normal operating conditions.

2.1.2 For derivation of scantlings of stiffeners, beams, girders, etc. the formulae in the Rules are normally based on elastic or plastic theory using simple beam models supported at one or more points and with varying degrees of fixity at the ends, associated with an appropriate concentrated or distributed load. Alternative methods will be considered.

2.2 Scantlings

2.2.1 Scantlings are generally based on the strength required to withstand loads imposed by the sea, payload, ballast, fuel and other operational loads. However, the Rules assume that the nature and stowage of the payload, ballast, etc. are such as to avoid excessive structural stresses, and deformation.

2.2.2 The design loads and pressures given in *Vol 1, Pt 5 Environmental Loads* are to be used with scantling formulae or direct calculation methods to derive scantlings based on maximum allowable stress or other suitable strength criteria.

2.2.3 Hull structural vibration resulting from cyclic loadings arising from the sea and other sources are to be such that the normal operation and structural integrity of the ship are not impaired.

2.2.4 Static loads are based on standard conditions defined in *Vol 1, Pt 5 Environmental Loads*, or determined from loading conditions submitted by the Builder.

2.2.5 Dynamic loadings are examined for both the local and global structures. These loadings are based upon the designer's stated operational and environmental conditions or the Rule minimum criteria, whichever is the greater.

2.2.6 Wave induced loads are considered both in the static condition, i.e. hydrostatic and pitching pressures, and in the dynamic mode, i.e. impact, slamming and hogging and sagging wave loading conditions.

2.2.7 Hull girder strength will in general require to be investigated dependent upon the length, configuration, proportions, proposed scenarios, etc. of the ship.

2.2.8 Structure in way of Replenishment at Sea, **RAS**, positions, cranes, heavy lift route points, weapon handling, etc. are to be designed in accordance with *Vol 1, Pt 4, Ch 1, 5 Military design requirements*. The equipment is to be designed in accordance with a specified standard(s), *see Vol 1, Pt 1, Ch 2, 1 Conditions for Classification*.

2.2.9 Scantling requirements in respect of miscellaneous items of structure such as local foundations, base plates, insert plates, bollards, etc. are not specifically indicated within these Rules. However, the acceptance of such items will be specially considered on the basis of experience, good practice and direct calculation where appropriate.

2.3 Definitions and structural terms

2.3.1 For the purpose of clarifying the nomenclature of items of structure referred to throughout the Rules, the following definitions are given:

- Secondary members are stiffeners supporting shell, deck or bulkhead plating, e.g. side/bottom/deck longitudinals, frames and beams, and transverse/ longitudinal bulkhead stiffeners.
- Primary members are those members supporting secondary members and will be the predominant members in grillage systems, e.g:
  - Bottom structure – floors, bottom and inner bottom transverse and girders.
  - Deck structure – deck transverses and girders.
  - Side structure – side transverses and side stringers.
  - Bulkheads – vertical webs and bulkhead stringers.

Deep web frames are members supporting primary members between bulkheads or decks, where additional support is necessary.

2.3.2 The fore end region structure is considered to include all structure forward of 0,7L_{R}.

2.3.3 The aft end region structure is considered to include all structure aft of 0,3L_{R}.

■ *Section 3* **Main hull structure**

3.1 General

3.1.1 The Rules are formulated to provide for scantling derivation for designs comprising the following structural framing systems. Details of the requirements are given in *Vol 1, Pt 6, Ch 2 Design Tools*.

(a) Primary/secondary stiffener systems - where, due to the relative differences in stiffness of the members, the secondary members are considered to act independently of, and are supported by, the primary members.

(a) Grillage systems - where the relative stiffness of the orthogonal stiffening is similar and work together to support the applied loads. The grillage system is in turn supported by major structural members such as bulkheads or decks.

3.1.3 For practical reasons of fabrication and continuity of structure, orthogonal systems using members of the same depth should not be employed. A minimum web depth difference of 40 mm is generally to be used to allow for the passage through the web at the intersections.

3.1.4 It is recognised that there will be a reduction in transverse ‘racking’ strength in association with the grillage stiffening system where the predominantly stiffer transverse web of the primary/secondary system is missing. In large areas of grillage systems the ‘racking’ strength, therefore, will be specially considered.

3.1.5 For NS1 and NS2 ships, longitudinal framing, in general, is to be adopted in the bottom shell, decks and inner bottom, with transverse or longitudinal framing at the side shell and longitudinal bulkheads. In NS3 ships, transverse or longitudinal framing may be universally adopted.

3.1.6 The adopted framing system whether longitudinal or transverse is required to be continuous. Where it is impracticable to comply with these requirements or where it is proposed to terminate the framing structure in way of other primary members such as the transom, bulkheads or integral tank boundaries, they are to be bracketed in way of their end connections to maintain the continuity of structural strength. Particular care is to be taken to ensure accurate alignment of the brackets. Brackets are in general to have soft toes and to terminate on structure that is capable of supporting the transmitted bending moment and forces.

3.1.7 The arrangement of the connection between any stiffener and bracket is to be such that at no point in the connection are the section modulus and inertia reduced to less than that of the stiffener with associated plating.

3.1.8 The arrangement of material is to be such as will ensure structural continuity. Abrupt changes of shape or section, sharp corners and points of stress concentration are to be avoided.

3.1.9 Where members abut on both sides of a bulkhead or similar structure, care is to be taken to ensure good alignment and continuity of strength.

3.1.10 The fitting of pillar bulkheads is preferable to pillars. The fitting of pillars is to be avoided in hangar and vehicle decks and where connected to the inner bottom. Where enhanced shock and blast requirements are specified, only pillar bulkheads may be fitted. When fitted, pillars and pillar bulkheads are to be in the same vertical line wherever possible, and elsewhere arrangements are to be made to transmit the out of line forces satisfactorily. The load at head and heel of pillars is to be effectively distributed and arrangements are to be made to ensure the adequacy and lateral stability of the supporting members.

3.1.11 End connections of structural members are to provide adequate end fixity and effective distribution of the load into the supporting structure.

3.1.12 The corners of large openings in the shell and decks from 0,25L_R to 0,75L_R are to be elliptical, parabolic or circular. Where predominantly unidirectional stress fields are anticipated, elliptical or parabolic corners are recommended. Where biaxial or torsional stress fields are expected, circular corners are recommended.

3.1.13 Where elliptical corners are arranged the major axis is to be fore and aft, the ratio of the major to minor axis is to be not less than 2 to 1 nor greater than 2,5 to 1, and the minimum half-length of the major axis is to be defined by l_1 in *Figure 2.3.1 Opening geometry* Where parabolic corners are arranged, the dimensions are also to be as shown in *Figure 2.3.1 Opening geometry*. An increase in plate thickness will not generally be required.

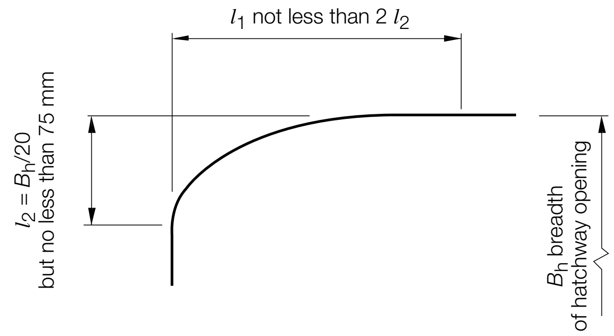


Figure 2.3.1 Opening geometry

3.1.14 Where circular corners are arranged, a radius not less than 1/20 of the breadth of the opening is to be used with a minimum of 75 mm. For circular corners, inserts of the size and extent shown in *Figure 2.3.2 Inserts in way of openings* will, in general, be required. The thickness of insert plates is to be not less than 25 per cent greater than the adjacent plating with a minimum increase of 4 mm. The increase need not exceed 7 mm.

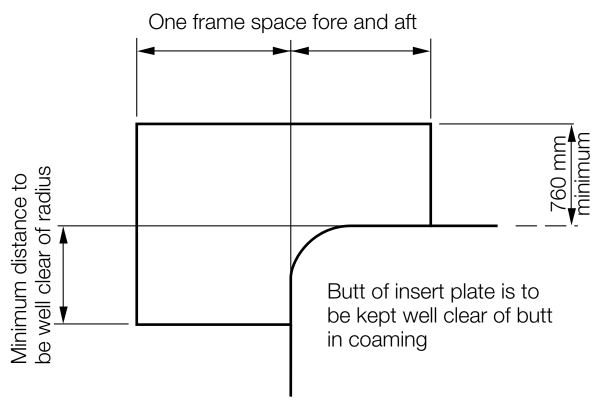


Figure 2.3.2 Inserts in way of openings

3.1.15 For other shapes of corner, inserts of the size and extent shown in *Figure 2.3.2 Inserts in way of openings* will, in general, be required.

3.1.16 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. In particular, manholes and similar openings are not to be cut in vertical or horizontal diaphragm plates in narrow cofferdams or in floors and double bottom girders close to their span ends, or below the heels of pillars, unless the stresses in the plating and the

panel buckling characteristics have been calculated and found satisfactory. The sizes of openings are to be in accordance with *Vol 1, Pt 3, Ch 2, 3.2 Primary members 3.2.9*.

3.1.17 Manholes, lightening holes and other openings are to be suitably framed and stiffened where necessary.

3.1.18 Provision is made for the free passage of air and water taking into account the pumping rates required.

3.1.19 Particular care is to be given to the positioning of drain holes to reduce stress concentrations and ensure adequate drainage from all parts of the ship's hull to the suctions. They are to be placed as close to the bottom as practicable.

3.1.20 Suitable arrangements are to be made to provide free passage of air from all parts of tanks to the air pipes. They are to be placed as close to the top of the tank as practicable. Air pipes of sufficient number and area are to be fitted to each tank in accordance with *Vol 1, Pt 3, Ch 4, 7 Air pipes*.

3.1.21 Air and drain holes, notches and scallops are to be kept at least 200 mm clear of the toes of end brackets and other areas of high stress. Openings are to be well rounded with smooth edges. Closely spaced scallops are not permitted.

3.1.22 Widely spaced air or drain holes, cut entirely in the web adjacent to, but clear of the welded connection, may be accepted, provided that they are of elliptical shape, or equivalent, to minimise stress concentrations, *see Figure 2.3.3 Air/Drain hole geometry*

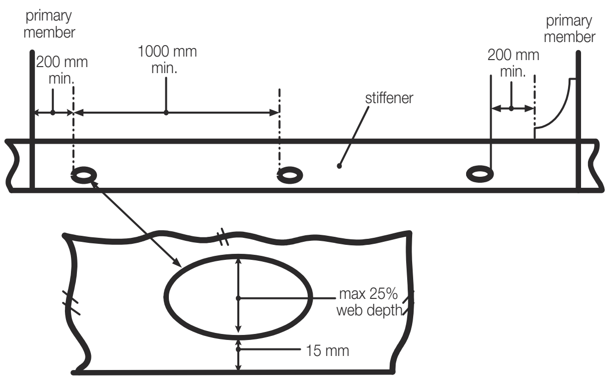


Figure 2.3.3 Air/Drain hole geometry

3.2 Primary members

3.2.1 The following guidelines for the design of primary members are to be adopted. Scantling requirements for primary members are given in *Vol 1, Pt 6, Ch 3 Scantling Determination*.

3.2.2 Primary members are to be so arranged as to ensure effective continuity of strength, and abrupt changes of depth or section are to be avoided. Where members abut on both sides of a bulkhead, or on other members, arrangements are to be made to ensure that they are in alignment. Primary members are to form a continuous line of support and, wherever possible, a complete ring system.

3.2.3 Primary members are to have adequate lateral stability and web stiffening and the stiffening structure is to be arranged to minimise hard spots and other sources of stress concentration.

3.2.4 Primary members are to be provided with adequate end fixity by end brackets or equivalent structure. The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint and effective distribution of the load from the member. Where a deck girder or transverse is connected to a vertical member on the shell or bulkhead, the scantlings of the latter may be required to be increased to provide adequate stiffness to resist rotation of the joint.

3.2.5 Where the primary member is supported by structure which provides only a low degree of restraint against rotation, the member is generally to be extended beyond the point of support and thereafter tapered and/or scarfed into the adjacent structure over a distance generally not less than two frame spaces.

3.2.6 Where primary members are subject to concentrated loads, particularly if these loads are out of line with the member web, additional strengthening may be required.

3.2.7 Where a member is continued over a point of support, such as a pillar or pillar bulkhead stiffener, the design of the end connection is to be such as to ensure the effective distribution of the load into the support. Brackets are generally required but alternative arrangements will be considered.

3.2.8 The thickness of the brackets supporting primary members is to be not less than that of the primary member web. The free edge of the bracket is to be stiffened.

3.2.9 Where openings are cut in the web or primary members, the depth of opening is not to exceed 50 per cent of the web depth, and the opening is to be so located that the edges are not less than 25 per cent of the web depth from the face plate. The length of opening is not to exceed the web depth or 60 per cent of the secondary member spacing, whichever is the greater, and the ends of the openings are to be equidistant from the corners of cut-outs for secondary members. Where larger openings are proposed, the arrangements and compensation required will be specially considered.

3.2.10 Openings are to have well rounded corners and smooth edges and are to be located having regard to the stress distribution and buckling strength of the panel in which they are situated.

3.2.11 Cut-outs for the passage of secondary members are to be designed to minimise the creation of stress concentrations. The breadth of cut-out is to be kept as small as practicable and the top edge is to be rounded, or the corner radii made as large as practicable. The extent of the direct connection to the web plating, or the scantlings of lugs or collars, is to be sufficient for the loads to be transmitted from the secondary member, *see also Vol 1, Pt 6, Ch 6, 5.5 Arrangement at intersection of primary and secondary members*

3.2.12 Stiffeners in areas likely to experience slamming, impact or dynamic loads are to be lugged or bracketed to the web of the primary member at their intersections, *see also Vol 1, Pt 6, Ch 6, 5.5 Arrangement at intersection of primary and secondary members*

3.3 Shell plating

3.3.1 Scantling requirements for shell plating are given in *Vol 1, Pt 6, Ch 3, 5 Shell envelope plating*.

3.3.2 The sheerstrake is generally to be taken as the side shell, locally reinforced in way of deck/hull connection. The amount of local reinforcement will be dependent upon the arrangement of structure and the proposed service.

3.3.3 In general, openings are not to be cut in the sheerstrake; however, if operational requirements dictate, openings that are less than 20 per cent of the depth of the sheerstrake may be accepted. Openings greater than 20 per cent of the depth of the sheerstrake will require special consideration.

3.3.4 Where large side shell openings, such as side aircraft lifts, are proposed, detailed calculations are to be submitted.

3.3.5 Where rounded gunwales are fitted, arrangements are to ensure a smooth transition from rounded gunwale to angled gunwale.

3.3.6 At the ends of superstructures where the side plating is extended and tapered to align with the bulwark plating, the transition plating is to be suitably stiffened and supported. Where freeing ports or other openings are essential in this plate, they are to be suitably framed and kept well clear of the free edge.

3.3.7 Sea-inlets, or other openings, are to have well rounded corners and, so far as is practicable, are to be kept clear of the bilge radius, chine or radiused sheerstrake. Arrangements are to be made to maintain the strength in way of the openings. Additional thickness is to be required in accordance with *Vol 1, Pt 6, Ch 3, 5.7 Sea inlet boxes*. Adequate provision is to be taken to prevent local resonance problems. Additional guidance for the design of sea-inlets or other openings, is given in *Vol 1, Pt 4, Ch 1, 8 Design guidance for the reduction of radiated noise underwater due to sea-inlets or other openings*.

3.3.8 Openings on or near the bilge radius may be accepted provided that they are of elliptical shape, or equivalent, to minimise stress concentrations and are, in general, to be kept clear of weld connections.

3.3.9 The scantlings of appendages (e.g. 'A' brackets) are covered in *Vol 1, Pt 3, Ch 3 Ship Control Systems*. However, in way of the hull penetrations, particular care will be required to be given to the strength and watertight integrity of the shell.

3.4 Shell framing

3.4.1 The scantlings of shell structure are to be determined in accordance with *Vol 1, Pt 6, Ch 3, 6 Shell envelope framing*

3.4.2 Longitudinal framing is, in general, to be adopted in the bottom, but special consideration will be given to proposals for transverse framing in this region, *see Vol 1, Pt 3, Ch 2, 3.1 General 3.1.5*

3.4.3 For NS1 and NS2 ships, the bottom and side longitudinals are to be continuous in way of both watertight and non-watertight floors, but equivalent arrangements will be specially considered.

3.4.4 Bottom and side longitudinals are to be supported by primary transverse structure such as bottom transverses, floors or bulkheads, generally spaced not more than 2,5 m apart in NS1 and NS2 ships, and 1,5 m in NS3 ships.

3.4.5 Bottom and side transverses, where fitted, are to be continuous and substantially bracketed at their end connections to side and deck transverses and bottom floors.

3.4.6 Bottom and side frames are to be effectively continuous and bracketed at their end connections to side frames, deck beams and bottom floors as appropriate. Side frames are to be supported by decks or stringers spaced not more than three metres apart.

3.4.7 Bottom girders and side stringers supporting transverse frames are to be continuous through transverse bulkheads and supporting structures. They are to be supported by deep transverse web frames, floors, bulkheads, or other primary structure, generally spaced not more than three metres apart.

3.4.8 For primary members the web stability, openings in the web and continuity and alignment are to be in accordance with *Vol 1, Pt 3, Ch 2, 3.2 Primary members 3.2.9*

3.4.9 For ships intended for beach landing operations, *see Vol 1, Pt 4, Ch 2, 8 Strengthening requirements for beach landing operations*.

3.4.10 For berthing and docking requirements, *see Vol 1, Pt 3, Ch 5, 10 Launch and recovery, berthing and dry-docking arrangements*

3.4.11 Where the shell framing is of unusual design or proportions, the scantlings are to be determined by direct calculation.

3.5 Single bottom structure

3.5.1 Scantling requirements for single bottom structure are given in *Vol 1, Pt 6, Ch 3, 7 Single bottom structures*.

3.5.2 The requirements of this section provide for single bottom construction in association with transverse and longitudinal framing systems, *see Vol 1, Pt 3, Ch 2, 3.1 General 3.1.5*

3.5.3 All girders are to extend as far forward and aft as necessary and care is to be taken to avoid any abrupt discontinuities. Where girders are cut at bulkheads, alignment and longitudinal strength are to be maintained.

3.5.4 Particular care is to be taken to ensure that the continuity of structural strength in way of the intersection of transverse floors and longitudinal girders is maintained. The face flats of such stiffening members are to be effectively connected.

3.5.5 The single bottom structure in way of the keel and girders is to be sufficient to withstand the forces imposed by dry-docking the ship, see *Vol 1, Pt 4, Ch 2, 8 Strengthening requirements for beach landing operations*

3.5.6 A continuous centreline girder is, in general, to be fitted in all ships throughout the length of the hull as far forward and aft as practicable.

3.5.7 Where the floor breadth at the upper edge exceeds 6,0 m, side girders are to be fitted at each side of the centre girder such that the spacing between the side and centre girders or between the side girders themselves is not greater than 3 m. In general, side girders where fitted are to be continuous, extend as far forward and aft as practicable and to terminate in way of bulkheads, deep floors or other primary transverse structure. In addition, continuous intercostal longitudinal stiffeners are to be fitted where the panel size exceeds the ratio 4 to 1.

3.5.8 In ships with a transversely framed bottom construction, the bottom shell plating is, in general, to be reinforced with additional continuous, or intercostal, longitudinal stiffeners. Alternative arrangements to be considered.

3.5.9 For ships intended for beach landing operations, *see Vol 1, Pt 4, Ch 2, 8 Strengthening requirements for beach landing operations*

3.5.10 In longitudinally framed ships, plate floors are to be fitted as given in *Vol 1, Pt 3, Ch 2, 3.4 Shell framing 3.4.4*. The connections with side transverse web frames are to be as required by *Vol 1, Pt 3, Ch 2, 3.4 Shell framing 3.4.6*. Additional transverse floors or webs are in general to be fitted at the half spacing of primary transverse structure in way of engine seatings, thrust bearings, pillars, skegs, bilge keels and the bottom of the ship forward.

3.5.11 The tops of the floors may be level from side to side. However, in ships having considerable rise of floor the depth of floors may require to be increased to maintain the required section modulus.

3.5.12 In general, the floors in way of the stern tubes, shaft brackets, etc. are to provide effective support for these items.

3.6 Double bottom structure

3.6.1 Scantlings of double bottoms are to be in accordance with *Vol 1, Pt 6, Ch 3, 8 Double bottom structures*.

3.6.2 Double bottoms are in general to be fitted in NS1 ships and are to extend from the collision bulkhead to the aft peak bulkhead, as far as this is practicable within the design and proper working of the ship. The specified subdivision and stability standard may contain additional requirements for the height and extent of the double bottom.

3.6.3 A double bottom is generally not required in way of watertight compartments used exclusively for the carriage of liquids, provided the safety of the ship in the event of bottom damage is not thereby impaired. Suitable scarfing arrangements are to be made to maintain continuity of the inner bottom.

3.6.4 The inner bottom is to be continued to the ship's side as far as practicable, in such a manner as to protect the bottom to the turn of bilge or chine.

3.6.5 The centreline girder and side girders are to extend as far forward and aft as practicable and care is to be taken to avoid any abrupt discontinuities. Where girders are cut at bulkheads, their alignment and longitudinal strength are to be maintained.

3.6.6 Small wells constructed in the double bottom structure are not to extend in depth more than necessary. A well extending to the outer bottom may, however, be permitted at the after end of the shaft tunnel of the ship. Other well arrangements (e.g. for lubricating oil under main engines) may also be considered provided they give protection equivalent to that afforded by the double bottom.

3.6.7 Sufficient manholes are to be cut in the inner bottom, floors and side girders to provide adequate access to, and ventilation of, all parts of the double bottom. Openings are to be in accordance with *Vol 1, Pt 3, Ch 2, 3.2 Primary members 3.2.9*

3.6.8 The number and position of manholes are to be such that access under service conditions is neither difficult nor dangerous.

3.6.9 Manholes and their covers are to be of an approved design or in accordance with a recognised National or International Standard.

3.6.10 Provision is to be made for the free passage of air and water from all parts of the tanks to the air pipes and suctions, account being taken of the pumping rates required.

3.6.11 Adequate access is also to be provided to all parts of the double bottom for future maintenance, surveys and repairs. The edges of all openings are to be smooth.

3.6.12 A plan showing the location of manholes and access openings within the double bottoms is to be submitted.

3.6.13 Manholes, lightening holes and other cut-outs are to be avoided in way of concentrated loads and areas of high shear. Details are given in *Vol 1, Pt 3, Ch 2, 3.1 General 3.1.16*

3.6.14 Air and drain holes, notches and scallops are to be in accordance with *Vol 1, Pt 3, Ch 2, 3.1 General 3.1.8*

3.6.15 The Rules are formed on the basis that access to double bottoms will be by means of manholes with bolted covers. However, alternative arrangements will be specially considered.

3.6.16 In way of ends of floors and girders and transverse bulkheads, the number and size of holes are to be kept to a minimum, the openings are to be circular or elliptical and edge stiffening may be required.

3.6.17 Holes are not to be cut in the centre girder, except in tanks at the forward and after ends of the ship or where tank widths are reduced unless additional stiffening and/or compensation is fitted to maintain the structural integrity.

3.6.18 Centreline and side girders are to be continuous and sufficient to withstand the forces imposed by dry-docking the ship, *see Vol 1, Pt 4 Military Design and Special Features*. Vertical stiffeners are to be fitted at every bracket floor.

3.6.19 Where the breadth of floor is greater than 6,0 m, additional side girders having the same thickness as the floors are to be fitted. The number of side girders is to be such that the distance between the side girders and centre girder and margin plate, or between the side girders themselves, does not exceed 3,0 m (for transversely framed ships, 5,0 m for longitudinally framed ships).

3.6.20 Side girders where fitted are to extend as far forward and aft as practicable and are in general to terminate in way of bulkheads, deep floors or other primary transverse structure.

3.6.21 Plate floors are, in general, to be continuous between the centre girder and the margin plate. Vertical stiffeners are to be fitted to the floors, the number and positions of these stiffeners being dependent on the arrangement of the double bottom structure.

3.6.22 In longitudinally framed ships, plate floors or equivalent structure are, in general, to be fitted in accordance with *Vol 1, Pt 3, Ch 2, 3.4 Shell framing 3.4.4* and additionally at the following positions:

(a) At every half spacing of primary transverse structure as given in *Vol 1, Pt 3, Ch 2, 3.4 Shell framing 3.4.4*, in way of the bottom of the ship forward of 0,8L_R.
(b) Underneath pillars and bulkheads.

3.6.23 In transversely framed NS3 ships, plate floors are to be fitted at every frame in the engine room, under bulkheads, in way of change in depth of double bottom and elsewhere at a spacing not exceeding 1,5 m.

3.6.24 Between plate floors, the shell and inner bottom are to be supported by bracket floors. The brackets are to have the same thickness as plate floors and are to be stiffened on the unsupported edge.

3.6.25 In longitudinally framed ships, the bracket floors are to extend from the centre girder and margin plate to the adjacent longitudinal, but in no case is the breadth of the bracket floor to be taken as less than 75 per cent of the depth of the centre girder. They are to be fitted at every frame at the margin plate, and those at the centre girder are to be spaced not more than 1,0 m apart.

3.6.26 In transversely framed ships, the breadth of the bracket floors, attaching the bottom and inner bottom frames to the centre girder and margin plate, is to be not less than 75 per cent of the depth of the centre girder, *see Figure 1.5.5 Transverse framing system*.

3.6.27 Inner bottom longitudinals are to be supported by inner bottom transverses, floors, bulkheads or other primary structure, generally spaced not more than 2,5 m apart in NS1 and NS2 ships, and 1,5 m in NS3 ships.

3.6.28 The inner bottom longitudinals are to be continuous through the supporting structure.

3.6.29 Inner bottom transverses are to be continuous and to be substantially bracketed at their end connections to bottom transverses, bottom floors and tank side brackets.

3.6.30 In general, whilst the fitting of pillars connecting to the inner bottom is to be avoided, where they are fitted, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Manholes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided. Where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

3.6.31 Double bottoms are to be tested in accordance with the requirements of *Vol 1, Pt 6, Ch 6, 6 Inspection and testing procedures* of the Rules.

3.6.32 The Rules are formed on the basis that access to double bottoms will be by means of manholes with bolted covers. However, alternative arrangements will be specially considered.

3.7 Deck structure

3.7.1 Scantlings of decks are to be in accordance with the requirements of *Vol 1, Pt 6, Ch 3, 10 Deck structures*.

3.7.2 Where an inner bottom is not fitted, consideration of the ship's stability and strength following bottom damage is required. It may be appropriate to consider designing the lowest deck to be watertight. This is to be determined in conjunction with the damage stability analysis, assuming bottom damage.

3.7.3 The deck plating is to be supported by transverse beams with fore and aft girders; by longitudinals with deck transverses, or alternatively, by a grillage system of orthogonal and primary structure as provided for in *Vol 1, Pt 3, Ch 2, 3.1 General 3.1.1* The transverse beams and deck transverses are to align with side main frames and side transverses respectively. For NS1 and NS2 ships, longitudinal framing is generally to be adopted, *see Vol 1, Pt 3, Ch 2, 3.1 General 3.1.5*

3.7.4 Where transversely stiffened, beams are to be fitted at every frame and bracketed to the side frames. Deck transverses should also be fitted at the ends of large openings in the deck.

3.7.5 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

3.7.6 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

3.7.7 The ends of beams, longitudinals, girders and transverses are to be effectively built into the adjacent structure, or equivalent arrangements provided.

3.7.8 Arrangements to prevent tripping are to be fitted on deep webs.

3.7.9 The deck plating and supporting structure are to be suitably reinforced in way of cranes, masts, and deck equipment or machinery.

3.7.10 Deck structures subject to concentrated loads are to be suitably reinforced. Where concentrations of loading on one side of a stiffening member may occur, such as out of line pillars, the member is to be adequately stiffened against torsion. Additional reinforcements may be required in way of localised areas of high stress.

3.7.11 The end connection of strength deck longitudinals to bulkheads are to provide adequate fixity and, so far as is practicable, direct continuity of longitudinal strength. For NS1 and NS2 ships, the strength deck longitudinals are to be continuous through transverse structure, including bulkheads, but alternative arrangements will be considered.

3.7.12 Transverses supporting deck longitudinals are, in general, to be spaced not more than 2,5 m apart in NS1 and NS2 ships, and 1,5 m in NS3 ships. They are to be aligned with primary side structure.

3.7.13 All openings are to be supported by an adequate framing system, pillar bulkheads or cantilevers. When cantilevers are used, the scantlings are to be determined by direct calculation.

3.7.14 Where stiffening members terminate in way of an opening they are to be attached to carlings, girders, transverses or coaming plates, in such a way as to minimise stress concentrations.

3.7.15 Other openings in the strength deck outside the line of major openings are to be kept to the minimum number consistent with operational requirements. Openings are to be arranged clear of other opening corners and, so far as possible, clear of one another. Where necessary, plate panels in which openings are cut are to be adequately stiffened against compression and shear buckling. The corners of all openings are to be well rounded and the edges smooth. Attention is to be paid to structural continuity and abrupt changes of shape, section or thickness are to be avoided.

3.7.16 Gutterway bars and spurn waters at the upper deck are to be so arranged that the effect of main hull stresses on them is minimised and that they do not cause stress concentrations in the deck or sheerstrake, *see also Vol 1, Pt 6, Ch 3, 3.6 Local reduction factors*

3.7.17 For flight decks, consideration should be given to the effect on fatigue life of welding attachments (e.g. cable trays and piping brackets) directly to the deck plating or stiffeners. It is recommended that attachments be made by other means or that the effect be accounted for in any fatigue analysis which may be undertaken.

3.7.18 It is recommended that the working areas of the weather deck have an anti-slip surface. Working areas of all decks where there is the possibility of leakage of fuel, hydraulic or other oils are to be provided with anti-slip deck coatings, or equivalent, and guard rails, as appropriate.

3.7.19 Where decks are sheathed with wood or other materials, details of the method of attachment are to be submitted, *see also Vol 1, Pt 6 Hull Construction in Steel*.

3.7.20 Where large or novel hatch openings are proposed, detailed calculations are to be submitted to demonstrate that the scantlings and arrangements in way of the openings are adequate to maintain continuity of structural strength.

3.7.21 Where large side shell openings such as side aircraft lifts are proposed, detailed calculations are to be submitted.

3.7.22 Pipe or cable runs through watertight decks are to be kept to a minimum and are to be fitted with suitable watertight glands of a type, approved and pressure tested for the maximum head of water indicated by any required damage stability calculations.

3.7.23 The specified subdivision and stability standard(s) may require all deck penetrations to be of a nominated standard.

3.7.24 Heat-sensitive materials are not to be used in pipe or cable runs which penetrate watertight decks, where deterioration of such systems in the event of fire would impair the watertight integrity of the deck.

3.7.25 The number of openings in watertight decks is to be reduced to the minimum compatible with the design and proper working of the ship. Where openings are permitted in watertight decks, they are to be provided with suitable closing devices in accordance with *Vol 1, Pt 3, Ch 4, 4 Watertight doors and hatches in watertight subdivision boundaries*.

3.8 Deep tank structure

3.8.1 The scantlings of deep tank structure are to be in accordance with the relevant Sections of *Vol 1, Pt 6 Hull Construction in Steel*.

3.8.2 Above the top of floors, the side shell structure of deep tanks is to be effectively supported by a system of primary framing with web frames, stringers, cross ties and/or perforated flats.

3.8.3 The maximum spacing of side shell transverses in longitudinally framed deep tanks is generally not to exceed 2,5 m in NS1 and NS2 ships, and 1,5 m in NS3 ships.

3.8.4 The maximum spacing of side shell web frames in transversely framed deep tanks is generally not to exceed five frame spaces. They are to extend from the tank top to the level of the lowest deck above the design waterline.

3.8.5 The maximum spacing of horizontal stringers is generally not to exceed 3,0 m.

3.8.6 Where decks terminate at deep tanks, suitable scarfing arrangements are to be arranged and the side shell supported by a stringer at deck level. The stringer can be either fully effective or acting as part of a grillage. Bulkhead stiffeners are to be supported at the deck level against tripping.

3.8.7 A centreline bulkhead is, generally, to be fitted in deep tanks which extend from side to side. The bulkhead may be intact or perforated as desired. If intact, the scantlings are to comply with the requirements of *Vol 1, Pt 6 Hull Construction in Steel* for tank boundary bulkheads. If perforated, they are to comply with the requirements of *Vol 1, Pt 6 Hull Construction in Steel* for wash plates. Where brackets from horizontal girders on the boundary bulkheads terminate at the centreline bulkhead, adequate support and continuity are to be maintained.

3.8.8 The thickness of any longitudinal bulkheads may be required to be increased to ensure compliance with the shear strength requirements of *Vol 1, Pt 6 Hull Construction in Steel*. In the case of a centreline or perforated wing bulkhead, the proportion of the total shear force absorbed by the bulkhead will be specially considered.

3.8.9 The thickness of plating of wash bulkheads may also be required to be increased to take account of shear buckling.

3.8.10 Where longitudinal wash bulkheads support bottom transverses, the lower section of the bulkhead is to be kept free of non-essential openings for a depth equal to 1,75 times the depth of the transverses. The plating is to be assessed for local buckling requirements.

■ *Section 4*
Bulkhead arrangements

4.1 General

4.1.1 Watertight bulkheads for NS2 and NS3 ships are, in general, to extend to the uppermost continuous deck, and their construction is to be in accordance with *Vol 1, Pt 6, Ch 3, 9 Bulkheads and deep tanks*. In the larger multidecked NS1 ships (e.g. Aircraft Carriers) the watertight bulkheads are generally to extend to the lowest continuous vertical limit of weathertightness determined by *Vol 1, Pt 3, Ch 2, 1.3 Watertight and weathertight integrity*

4.1.2 Where permitted by the stability and subdivision standard, certain openings below the deck described in *Vol 1, Pt 3, Ch 2, 4.1 General 4.1.1* may be allowed, *see Vol 1, Pt 1, Ch 2, 1.1 Framework of Classification 1.1.9*. In all cases these openings must be kept to a minimum and provided with means of closing to watertight standards.

4.1.3 The number of openings in watertight bulkheads is to be reduced to the minimum compatible with the design and proper working of the ship. Where openings are permitted in bulkheads they are to be provided with suitable closing devices in accordance with *Vol 1, Pt 3, Ch 4, 4 Watertight doors and hatches in watertight subdivision boundaries*

4.1.4 Bulkheads forming the boundaries to citadels and zones as defined in *Vol 1, Pt 4, Ch 1, 7 Design guidance for nuclear, biological and chemical defence* other than watertight bulkheads, are usually specified to be gastight. *See also Vol 1, Pt 3, Ch 2, 4.7 Gastight bulkheads*. Where specified, LR can assess the gastight integrity of defined gastight boundaries, *see Vol 1, Pt 6, Ch 6, 6.8 Gastight testing*.

4.1.5 Pipe or cable runs through watertight bulkheads are to be kept to a minimum and are to be fitted with suitable watertight glands of a type, approved and pressure tested for the maximum head of water indicated by any required damage stability calculations.

4.1.6 The specified subdivision and stability standard(s) may require all bulkhead penetrations to be of to a nominated standard.

4.1.7 Heat-sensitive materials are not to be used in pipe or cable runs which penetrate watertight bulkheads, where deterioration of such systems in the event of fire would impair the watertight integrity of the deck.

4.1.8 Partial or main bulkheads are to be located beneath the ends of superstructures and deckhouses and masts and heavy items of equipment such as weapon systems to support and transmit the static and dynamic forces into the hull structure. They are to be of sufficient strength and rigidity to carry the concentrated loads imposed on them and maintain alignment where necessary.

4.2 Number and disposition of watertight bulkheads

4.2.1 In general, the number and disposition of bulkheads are to be arranged to suit the requirements for subdivision, floodability and damage stability, and are to be in accordance with the specified subdivision and stability standard(s).

4.2.2 Main transverse watertight bulkheads are to be spaced at reasonably uniform intervals. Where non-uniform spacing is unavoidable and the length of a compartment is unusually large, the transverse strength of the ship is to be maintained by fitting of web frames, increased framing, etc. Details of the proposed arrangements are to be submitted.

4.2.3 All ships are to have a collision bulkhead, an after peak bulkhead and a watertight bulkhead at each end of all main and auxiliary machinery spaces. Additional watertight bulkheads are to be fitted so that the total number of bulkheads is at least in accordance with *Table 2.4.1 Minimum number of bulkheads*.

Table 2.4.1 Minimum number of bulkheads

Length, L_R, in metres	Total number of bulkheads	
	Machinery amidships	Machinery aft *see* Note
$L_R \leq 65$	4	3
$65 < L_R \leq 85$	4	4
$85 < L_R \leq 90$	5	5
$90 < L_R \leq 105$	5	5
$105 < L_R \leq 115$	6	5
$115 < L_R \leq 125$	6	6
$125 < L_R \leq 145$	7	6
$145 < L_R \leq 165$	8	7
$165 < L_R \leq 190$	9	8
$L_R > 190$	To be considered individually	
Note With after peak bulkhead forming after boundary of machinery space.		

4.2.4 Proposals to dispense with one or more of these bulkheads will be considered, subject to suitable structural compensation, if they interfere with the operational requirements.

4.2.5 A main transverse bulkhead is to be located at the position where the ship sues during docking.

4.3 Collision bulkheads

4.3.1 The collision bulkhead is to be positioned as detailed in *Table 2.4.2 Collision bulkhead position distance of collision bulkhead aft of fore end of LR, in metres* . However, consideration will be given to proposals for the collision bulkhead to be positioned slightly further aft on an arrangement (b) ship, but not more than 0,08 L_R from the fore end of L_R, provided that the application is accompanied by calculations showing that flooding of the space forward of the collision bulkhead will not result in any part of the bulkhead deck becoming submerged, or any unacceptable loss of stability. The length L_R is as defined in *Table 2.4.1 Minimum number of bulkheads*.

4.3.2 For ships with pronounced rake of stem, the position of the collision bulkhead will be specially considered.

4.3.3 No accesses or ventilation ducts are to be fitted in collision bulkheads. In designs where it would be impracticable to arrange access to the fore peak other than through the collision bulkhead, access may be permitted if specified. Where accesses

are provided, the openings are to be as small as practicable and positioned as far above the design waterline as possible, in any event, no lower than the damage control deck. Access is to be by manholes with bolts spaced at a watertight pitch.

4.3.4 Pipe runs or cable runs are only to be fitted in the collision bulkhead if specified in the subdivision and stability standard(s).

4.4 Aft peak bulkhead

4.4.1 NS1 and, where practicable, NS2 ships, are to have an aft peak bulkhead generally enclosing the sterntube and rudder trunk in a watertight compartment. In twin screw ships where the bossing ends forward of the aft peak bulkhead, the sterntubes are to be enclosed in suitable watertight spaces inside or aft of the shaft tunnels. The stern gland is to be situated in a watertight shaft tunnel or other watertight space separate from the stern tube compartment and of such volume that, if flooded by leakage through the stern gland, the ship will remain fully operational. The arrangement in NS3 ships, and in NS2 ships where it is impracticable to meet the aforementioned conditions, will be specially considered based on the integrity of the gland sealing arrangements and damage stability requirements.

Table 2.4.2 Collision bulkhead position distance of collision bulkhead aft of fore end of L_R, in metres

Arrangement	Length L_R, in metres	Minimum	Maximum
(a)	≤ 200	$0{,}05L_R$	$0{,}08L_R$
	> 200	10	$0{,}08L_R$
(b)	≤ 200	$0{,}05L_R - f_1$	$0{,}08L_R - f_1$
	> 200	$10\text{m} - f_2$	$0{,}08L_R - f_2$

Symbols and definitions

- $f_1 = G/2$ or $0{,}015L_R$, whichever is the lesser
- $f_2 = G/2$ or 3 m, whichever is the lesser
- G = projection of bulbous bow forward of fore perpendicular, in metres

Arrangement (a)	A ship that has no part of its underwater body extending forward of the fore perpendicular
Arrangement (b)	A ship with part of its underwater body extending forward of the fore perpendicular, (e.g. bulbous bow)

4.5 Height of bulkheads

4.5.1 The collision bulkhead is normally to extend to the uppermost continuous deck or, in the case of a ship with combined bridge and forecastle or a long superstructure which includes a forecastle, to the superstructure deck. However, if a ship is fitted with more than one complete superstructure deck, the collision bulkhead may be terminated at the first deck above the vertical limit of watertight integrity. Where the collision bulkhead extends above the vertical limit of watertight integrity, the extension need only be to weathertight standards.

4.5.2 The aft peak bulkhead may terminate at the first deck above the load waterline, provided that this deck is made watertight to the stern or to a watertight transom floor.

4.5.3 The remaining watertight bulkheads are to extend as required by *Vol 1, Pt 3, Ch 2, 4.1 General 4.1.1*. In ships of unusual design, the height of the bulkheads will be specially considered.

4.6 Watertight recesses, flats, openings and loading ramps

4.6.1 Watertight recesses in bulkheads are to be avoided whenever possible.

4.6.2 Where watertight bulkhead stiffeners are cut in way of watertight doors in the lower part of a bulkhead, the opening is to be suitably framed and reinforced. Where stiffeners are not cut but the spacing between the stiffeners is increased on account of

watertight doors, the stiffeners at the sides of the doorways are to be increased in depth and strength so that the efficiency is at least equal to that of the unpierced bulkhead, without taking the stiffness of the door frame into consideration.

4.6.3 In collision bulkheads, any recesses or steps in the bulkhead are to fall within the limits of bulkhead positions given in*Vol 1, Pt 3, Ch 2, 4.3 Collision bulkheads 4.3.1*. If a step occurs above the virtual limit of watertight integrity the deck need also only be to weathertight standards in way of the step, unless the step forms the crown of a tank, in which case the requirements for deep tank structures are to be complied with.

4.6.4 In ships fitted with bow doors, in which a sloping loading ramp forms part of the collision bulkhead above the virtual limit of watertight integrity, that part of the ramp which is more than 2,30 m above the virtual limit of watertight integrity may extend forward of the minimum limit specified in *Table 2.4.2 Collision bulkhead position distance of collision bulkhead aft of fore end of LR, in metres* Such a ramp is to be weathertight over its complete length.

4.7 Gastight bulkheads

4.7.1 Where an assessment of gastight integrity is required the scantlings of gastight bulkheads are to be in accordance with *Vol 1, Pt 6 Hull Construction in Steel*.

4.7.2 Where bulkheads are required to be gastight and where it is proposed to pierce such bulkheads for the passage of cables, pipes, vent trunking, etc. gastight glands are to be provided to maintain the gastight integrity.

4.8 Tank bulkheads

4.8.1 For bulkheads in way of partially filled compartments or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

4.8.2 The scantlings of deep tank bulkheads are to be in accordance with *Vol 1, Pt 6 Hull Construction in Steel*.

4.8.3 Air and sounding pipes are to comply with the requirements of *Vol 1, Pt 3, Ch 4, 7 Air pipes*.

4.9 Cofferdams

4.9.1 Tanks carrying fuel oil or lubricating oil are to be separated by cofferdams from those carrying fresh water. Cofferdams are to be fitted between freshwater tanks and black or grey water tanks.

4.9.2 Lubricating oil tanks are also to be separated by cofferdams from those carrying fuel oil unless:

(a) Common boundaries of lubricating oil and fuel oil tanks have full penetration welds.
(b) The tanks are arranged such that the fuel oil tanks are not generally subjected to a head of oil in excess of that in the adjacent lubricating oil tanks.

4.9.3 If fuel oil tanks are necessarily located within or adjacent to the machinery spaces, their arrangement is to be such as to avoid direct exposure of the bottom from rising heat resulting from a machinery or hazardous space fire.

4.9.4 Adequate access is to be provided to all parts of the cofferdams for future maintenance, surveys and repairs. The edges of openings are to be smooth.

4.10 Watertight tunnels and passageways

4.10.1 Sterntubes are to be enclosed in watertight spaces of moderate volume. In addition, arrangements are to be made to minimise the danger of water penetrating into the ship in case of damage to the stern tube. Normally the stern gland is to be situated in a watertight shaft tunnel or other watertight space separate from the stern tube compartment and of such volume that, if flooded by leakage through the stern gland, the vertical limit of watertight integrity, *see Vol 1, Pt 3, Ch 2, 1.3 Watertight and weathertight integrity*, will not be submerged.

4.11 Means of escape

4.11.1 The arrangement of the hull is to be such that all under deck compartments are as accessible as practicable and provided with a satisfactory means of escape in accordance with a specified standard(s). Access and escape hatches to the machinery and tanks are not to be obstructed by deck coverings or furniture.

4.12 Carriage of low flash point fuels

4.12.1 For ships having fuel oil with a flash point below 60°C the arrangement for the storage, distribution and utilisation of the fuel oil is to be such that the safety of the ship and persons on board is preserved, having regard to the fire and explosion hazards.*See Vol 2, Pt 7, Ch 3, 2 Fuel oil - General requirements*

■ *Section 5*
Fore and aft end arrangements

5.1 General

5.1.1 In general the main hull structural arrangements as defined in *Vol 1, Pt 3, Ch 2, 3.3 Shell plating* are to extend as far forward and aft as possible.

5.1.2 The requirements of this Section apply to the fore and aft ends and relate to structure situated in the region forward of $0{,}7L_R$ and aft of $0{,}3L_R$ respectively.

5.1.3 Certain ships will require additional strengthening for bottom forward slamming and bow flare slamming. The scantlings of the hull structure forward are to be determined from *Vol 1, Pt 6 Hull Construction in Steel*, using the loads specified in *Vol 1, Pt 5, Ch 3, 3 Loads on shell envelope*.

5.1.4 Where the stern overhang is significant, or large masses are placed on the stern, the strength of the aft end structure will be specially considered, *see Vol 1, Pt 3, Ch 5, 10.4 Dry-docking loads*

5.2 Structural continuity

5.2.1 The Rules provide for both longitudinal and transverse framing systems.

5.2.2 Where the shell, deck and inner bottom are longitudinally framed in the midship region, this system of framing is to be carried forward and aft as far as possible.

5.2.3 End connections of longitudinals to bulkheads are to provide adequate fixity, lateral support and as far as practicable, direct continuity of longitudinal strength, *see also Vol 1, Pt 3, Ch 2, 3 Main hull structure*.

5.2.4 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt structural changes.

5.2.5 Where longitudinal framing terminates and is replaced by a transverse system, adequate arrangements are to be made to avoid an abrupt changeover. Where a forecastle is fitted extending forward from $0{,}85L_R$, longitudinal framing at the upper deck and topsides is generally to be continued forward of the aft bulkhead of this superstructure.

5.2.6 Where a superstructure or poop is fitted extending forward of $0{,}15L_R$, longitudinal framing at the upper deck and topsides is generally to be continued aft of the forward bulkhead of this superstructure.

5.2.7 The forecastle side plating may be a continuation of the side shell plating or fitted as a separate assembly. The side plating is to be stiffened by side frames effectively connected to the deck structure. Deep webs are to be fitted to ensure overall rigidity.

5.2.8 Forecastles and bulwarks are to be constructed in accordance with the scantlings indicated in *Vol 1, Pt 6, Ch 3, 1 General*

5.3 Minimum bow height and extent of forecastle

5.3.1 The requirements regarding minimum bow height given in *Vol 1, Pt 3, Ch 2, 5.3 Minimum bow height and extent of forecastle 5.3.2* are to be complied with. Only in exceptional circumstances and in specialist ships will any relaxation be given to this requirement where it interferes with the safe operation of the vessel. In such cases, due consideration is to be given to the clearing of seawater from the forecastle deck. The effects on strength and stability are also to be considered.

5.3.2 All sea-going ships are to be fitted with forecastles, or increased sheer on the upper deck or equivalent, such that the distance from the waterline design draught to the top of the exposed deck at side at the F.P. is not less than:

$$H_b = \left(6075\left(\frac{L_R}{100}\right) - 1875\left(\frac{L_R}{100}\right)^2 + 200\left(\frac{L_R}{100}\right)^3\right) \times \left(2,08 + 0,609C_b - 1,603C_{wf} - 0,0129\left(\frac{L_R}{d_1}\right)\right)$$

where

C_b = block coefficient

L_R = Rule length, in m

H_b = minimum bow height, in mm

d_1 = draught at 85 per cent of the depth, *D*, *see Vol 1, Pt 3, Ch 1, 5.2 Principal particulars 5.2.10*.

C_{wf} = waterplane area coefficient forward of midships $A_{wf}/\{(L_R/2) \times B\}$

B = moulded breadth, in m

A_{wf} = is the forward waterplane area at draught d_1, in m^2.

5.3.3 Ships shall have additional reserve of buoyancy in the fore end region to ensure sufficient longitudinal righting energy to recover from bow immersion in a seaway and be designed to prevent the excessive shipping of green seas.

5.3.4 Ships which are designed to suit exceptional operational requirements, restricted in their service to service area **SA4**, or of novel configuration will be specially considered on the basis of the Rules.

5.3.5 Where the bow height required in *Vol 1, Pt 3, Ch 2, 5.3 Minimum bow height and extent of forecastle 5.3.2* is obtained by increased sheer, the sheer shall extend for at least 15 per cent of the length of the ship measured abaft the forward end of L_R. Where it is obtained by fitting a forecastle, the forecastle shall extend from the stem to a point at least 0,07L_R abaft the forward end of L_R.

5.4 Bow crumple zone

5.4.1 In general the bow crumple zone is that space forward of the collision bulkhead. Embarked personnel or crew accommodation and the carriage of fuel, hazardous materials and other oils are not permitted in the bow crumple zone.

5.5 Deck structure

5.5.1 The scantlings of the deck structure are to comply with *Vol 1, Pt 6, Ch 3, 10 Deck structures*.

5.5.2 The deck plating thickness and supporting structure are to be suitably reinforced in way of anchor windlass, other deck machinery, and in way of cranes, masts or derrick posts, RAS stump masts, and weapon launching positions, etc.

5.5.3 Where large openings are arranged at lower decks near the side shell, it may be necessary to increase the adjacent deck structure to ensure effective support for side framing.

5.5.4 In NS1 and NS2 ships, on decks aft of the after cutup, deep beams are generally to be fitted in way of web frames. Deck girders are generally to be spaced not more than 3,0 m apart and integrated with the primary structure forward.

5.5.5 Requirements for the arrangement and geometry of deck openings are given in *Vol 1, Pt 3, Ch 1, 3.1 Alternative arrangements and calculation methods* and *Vol 1, Pt 3, Ch 1, 3.1 Alternative arrangements and calculation methods*. The scantlings of any inserts required are to be in accordance with *Vol 1, Pt 6 Hull Construction in Steel*.

5.6 Shell envelope plating and framing

5.6.1 The scantlings of bar keels in the forward end are to be the same as that required in the midship region, *see Table 3.2.1 Minimum structural requirements*

5.6.2 The thickness and width of plate keels in the forward region are to be the same as that required in the midship region.

5.6.3 The scantlings of plate stems are to be determined from *Vol 1, Pt 6, Ch 3, 5 Shell envelope plating* Plate stems are to be supported by horizontal diaphragms positioned in line with the side stringers or perforated flats with intermediate breasthook diaphragms. Diaphragms are to be spaced not more than 1,5 m apart, measured along the stem. Where the stem plate radius is large, a centreline stiffener or web will be required.

5.6.4 The thickness of side shell and sheerstrake plating in the forward region is to be not less than the values required by *Vol 1, Pt 6, Ch 3, 5 Shell envelope plating*, but may be required to be increased locally on account of high shear forces, in accordance with *Vol 1, Pt 6, Ch 4, 3.2 Determination of critical sections*

5.6.5 The shell plating may be required to be increased in thickness locally in way of openings such as hawse pipes and sonar domes, where fitted.

5.6.6 The shell plating is to be increased in thickness locally in way of a bulbous bow, *see Vol 1, Pt 3, Ch 2, 5.10 Bulbous bows*.

5.6.7 Sea inlet and other openings are to be in accordance with *Vol 1, Pt 3, Ch 2, 3.3 Shell plating 3.3.6*

5.6.8 The bottom longitudinals are to be continuous in way of both watertight and non-watertight floors.

5.6.9 Where the shape of the after hull is such that there are large flat areas, particularly in the vicinity of the propellers, additional primary supports for the secondary stiffening may be required. Their extent and scantlings will be specially considered.

5.7 Single and double bottom structure

5.7.1 The general requirements of *Vol 1, Pt 3, Ch 2, 3.5 Single bottom structure* and *Vol 1, Pt 3, Ch 2, 3.6 Double bottom structure* apply.

5.7.2 The minimum depth of centre girder forward is generally to be the same as that required in the midship region.

5.7.3 Where the height of the double bottom varies, structural continuity is to be maintained. An inner bottom where fitted is to be gradually sloped over an adequate longitudinal extent. Knuckles in the plating are to be arranged close to plate floors. Otherwise, suitable scarfing arrangements are to be made.

5.7.4 For ships of full form, in fore peak and deep tank spaces, the floors and bottom transverses are to be supported by a centreline girder or a centreline wash bulkhead. In other cases the centreline girder is to be carried as far forward as practicable. The floor panels and the upper edges of the floors and centreline girder are to be suitably stiffened.

5.7.5 In aft peak spaces, floors are to be arranged at every frame. For details and scantlings, *see Vol 1, Pt 6, Ch 3, 7.5 Single bottom structure in machinery spaces*

5.7.6 Provision is to be made for the free passage of water and air from all parts of single or double bottoms as required by *Vol 1, Pt 3, Ch 2, 3.1 General 3.1.18*.

5.8 Fore peak structure

5.8.1 The requirements given in this Section apply to the arrangement of primary structure supporting the fore peak side shell and bulbous bow, the arrangement of wash bulkheads and perforated flats. The scantlings of structure in the fore peak is to be in accordance with the relevant Sections of *Vol 1, Pt 6 Hull Construction in Steel*.

5.8.2 The bottom of the peak space is generally to be transversely framed. Longitudinally framed bottom structure will be specially considered.

5.8.3 Above the floors, transverse side framing is to be supported by horizontal side stringers, cross ties and/or perforated flats.

5.8.4 Suitable transverses or deep beams are to be arranged at the top of the tank and at perforated flats to provide end rigidity to the side transverses.

5.8.5 Wash bulkheads are to have an area of perforations not less than five per cent nor more than 10 per cent of the area of the bulkhead. The plating is to be suitably stiffened in way of openings. Stiffeners are to be bracketed at top and bottom.

5.9 Aft peak structure

5.9.1 The scantlings of aft peak structure are to be as required by the relevant Sections of *Vol 1, Pt 6 Hull Construction in Steel*. The plating thickness is to be increased locally in way of the sterntube gland.

5.9.2 Floors are to be arranged at every frame space and are to be carried to a suitable height, and at least to above the stern tube, where fitted. Floors are to be adequately stiffened. In way of propeller shaft brackets, rudder post or rudder horn, the floors are generally to be carried to the top of the space and are to be of increased thickness. The extent and amount of the increase will be specially considered, account being taken of the arrangements proposed.

5.9.3 Above the floors, transverse side framing is to be supported by horizontal stringers, cross ties and/or perforated flats.

5.9.4 Suitable transverses or deep beams are to be arranged at the top of the tank to provide end rigidity to the side transverses.

5.9.5 A centreline wash bulkhead is to be arranged in the upper part of the aft peak space. Additional wash bulkheads are to be fitted port and starboard where the width of the tank exceeds 20 m.

5.9.6 The plating is to be suitably stiffened in way of openings, and the arrangement of openings is to be such as to maintain adequate shear rigidity.

5.9.7 The position and height of the after peak bulkhead are to be in accordance with the requirements of *Vol 1, Pt 3, Ch 2, 4.4 Aft peak bulkhead*.

5.9.8 Centre and side girders where fitted are to be bracketed to the transom framing members by substantial knees. Hard spots are to be avoided in way of the end connections and care is to be taken to ensure that the stiffening member to which the transom knee is attached can satisfactorily carry the load.

5.10 Bulbous bows

5.10.1 Where a bulbous bow is fitted, the structural arrangements are to be such that the bulb is adequately supported and integrated into the fore peak structure.

5.10.2 At the fore end of the bulb the structure is generally to be supported by horizontal diaphragm plates spaced generally 1,0 m apart in conjunction with a deep centreline web.

5.10.3 In general, vertical transverse diaphragm plates are to be arranged in way of the transition from the peak framing to the bulb framing.

5.10.4 In way of a wide bulb, additional strengthening in the form of a centreline wash bulkhead is generally to be fitted.

5.10.5 In way of a long bulb, additional strengthening in the form of transverse wash bulkheads or substantial web frames spaced about five frame spaces apart are generally to be fitted.

5.10.6 The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness is to be the same as that required for plated stems.

■ *Section 6*
Machinery space arrangements

6.1 General

6.1.1 Requirements particular to machinery spaces, including protected machinery casings and engine seatings only, are given in this Section. For other scantlings and arrangement requirements, *see* the relevant section in this Chapter.

6.1.2 Requirements for the scantlings of structure in machinery spaces are to be in accordance with the relevant sections of *Vol 1, Pt 6, Ch 3, 13 Machinery and raft seatings*.

6.1.3 In addition, the requirements of *Vol 2, Pt 1, Ch 3, 5.1 Machinery spaces 5.1.4* are to be complied with.

6.2 Structural configuration

6.2.1 Requirements are given for ships constructed using either a transverse or longitudinal framing system, or a combination of the two.

6.2.2 Machinery space stiffening is generally to be arranged in the same manner as structure immediately forward and aft of the space. For NS1 and NS2 ships this will generally be longitudinal. Machinery spaces adjacent to the aft peak bulkhead may be constructed using a transverse framing system or a combination of longitudinal and transverse.

6.3 Structural continuity

6.3.1 Suitable scarfing arrangements are to be made to ensure continuity of strength and the avoidance of abrupt discontinuities where structure which contributes to the main longitudinal strength of the ship is omitted in way of a machinery space.

6.3.2 Where the longitudinal framing terminates and is replaced by transverse framing, a suitable scarfing arrangement of the longitudinal framing is to be arranged.

6.4 Deck structure

6.4.1 The corners of machinery space openings are to be of suitable shape and design to minimise stress concentrations.

6.4.2 Where a transverse framing system is adopted, deck beams are to be supported by a suitable arrangement of longitudinal girders in association with pillars or pillar bulkheads. Deep beams are to be arranged in way of the ends of engine casings and also in line with side web frames where fitted.

6.4.3 Where a longitudinal framing system is adopted, deck longitudinals are to be supported by deck transverses in association with pillars or pillar bulkheads. The maximum spacing of transverses is given in *Vol 1, Pt 3, Ch 2, 6.5 Side shell structure 6.5.2*. Deck transverses are to be in line with side transverses or web frames.

6.4.4 Machinery casings are to be supported in accordance with the requirements of *Vol 1, Pt 3, Ch 2, 6.7 Machinery casings* .

6.4.5 The scantlings of lower decks or flats are generally to be as given in *Vol 1, Pt 6, Ch 3, 10 Deck structures*. However, in way of concentrated loads such as those from boiler bearers or heavy auxiliary machinery, etc. the scantlings of deck structure will be specially considered, taking account of the actual loading.

6.4.6 In way of machinery space openings, etc. particularly towards the aft end, decks or flats are to have sufficient strength where they are intended to provide effective primary support to side framing, webs or transverses.

6.4.7 Where decks terminate at a machinery space bulkhead, suitable scarfing arrangements are to be arranged. The side shell of the machinery space is generally to be supported by a stringer at deck level. The stringer can be either fully effective or acting as part of a grillage. Bulkhead stiffeners at the deck level are to be supported against tripping.

6.4.8 Machinery space bulkheads with no supporting decks are to have suitable primary stiffening similar to that provided for the side shell in *Vol 1, Pt 3, Ch 2, 6.5 Side shell structure* .

6.5 Side shell structure

6.5.1 The side shell structure of machinery spaces is to be effectively supported by a system of primary framing with web frames and stringers. General requirements for web frames are given in this Section for both longitudinal and transverse framing systems.

6.5.2 The maximum spacing of side shell transverses in longitudinally framed machinery spaces is generally not to exceed 2,5 m in NS1 and NS2 ships, and 1,5 m in NS3 ships.

6.5.3 The maximum spacing of side shell web frames in transversely framed machinery spaces is generally not to exceed five frame spaces. They are to extend from the tank top to the level of the lowest deck above the design waterline.

6.5.4 The maximum spacing of stringers is generally not to exceed 3,0 m.

6.6 Double and single bottom structure

6.6.1 For the required extent of double bottom structure, *see Vol 1, Pt 3, Ch 2, 3.6 Double bottom structure*.

6.6.2 In the bottom structure sufficient fore and aft girders are to be arranged in way of the main machinery to effectively distribute its weight and to ensure adequate rigidity of the structure. In midship machinery spaces these girders are to extend for the full length of the space and are to be carried aft to support the foremost shaft tunnel bearing. This extension beyond the after bulkhead of the machinery space is to be for at least three transverse frame spaces, aft of which the girders are to scarf into the structure. Forward of the forward machinery space bulkhead, the girders are to be tapered off over three frame spaces and effectively scarfed into the structure. In machinery spaces in the aft end of the ship the girders are to be carried as far aft as practicable and the ends effectively supported by web frames or transverses. Care is to be taken to avoid any abrupt changes or discontinuities.

6.6.3 Where, in NS3 ships, the bottom is transversely framed, plate floors are to be fitted at every frame in the machinery space and under the main machinery, rafts, seatings and thrust bearing.

6.6.4 Where the bottom is longitudinally framed, plate floors are to be fitted at a maximum spacing of 2,5 m in NS1 and NS2 ships, and 1,5 m in NS3 ships in the machinery space under the main machinery, rafts, seatings and thrust bearing.

6.6.5 The minimum depth of the centre girder and its thickness are to be at least the same as required in way of other spaces amidships. Where the height of inner bottom in the machinery spaces differs from that in adjacent spaces, continuity of longitudinal material is to be maintained. In ships with a double bottom it is to be achieved by sloping the inner bottom over an adequate longitudinal extent. The knuckles in the plating are to be arranged close to plate floors.

6.6.6 Margin plates and drainage wells are to be provided as necessary and will be subject to special consideration.

6.6.7 Suitable arrangements are to be made to provide free passage of water from all parts of the bilge to the pump suctions. General requirements are given in *Vol 1, Pt 3, Ch 2, 3.1 General 3.1.18*.

6.6.8 Watertight floors, or floors forming boundaries of tank spaces, are also to comply with *Vol 1, Pt 3, Ch 2, 6.8 Integral fuel tanks*.

6.6.9 Where practicable, side girders outboard of the engines are to be fitted and are to line up with the side girders in adjacent spaces.

6.7 Machinery casings

6.7.1 The scantlings and arrangements of exposed casings protecting machinery openings are to be in accordance with *Vol 1, Pt 6, Ch 3, 11 Superstructures, deckhouses and bulwarks*.

6.7.2 Where casing sides act as girders supporting decks over, care is to be taken that access openings do not seriously weaken the structure. Openings are to be effectively framed and reinforced if necessary. Particular care is to be paid to stiffening where the casing supports the funnel or exhaust uptakes.

6.7.3 Machinery casings are to be supported by a suitable arrangement of deep beams or transverses and longitudinal girders in association with pillars or pillar bulkheads. In way of particularly large machinery casing openings, cross ties may be required, and these are to be arranged in line with deep beams or transverses. Where casing stiffeners carry loads from deck transverses, girders, etc. or where they are in line with pillars below, they are to be suitably reinforced.

6.7.4 Casing bulkheads are to be made gastight and the access doors are to be of a gastight self-closing type.

6.8 Integral fuel tanks

6.8.1 The scantlings of deep tank bulkheads are to be in accordance with *Vol 1, Pt 6, Ch 3, 9 Bulkheads and deep tanks*.

6.8.2 Fuel oil tanks situated within the machinery space are generally to comply with the requirements given in *Vol 1, Pt 6 Hull Construction in Steel*

6.9 Machinery seatings

6.9.1 Requirements on the scantlings of structure for machinery seatings are given in *Vol 1, Pt 6, Ch 3, 13 Machinery and raft seatings*.

6.9.2 This section applies to machinery or machinery raft seatings that are directly supported by the ship's hull. They are to be effectively secured to the hull and to be of adequate scantlings to resist the various gravitational, thrust, torque, dynamic and vibratory forces which may be imposed on them. Due attention is to be paid to the stiffness requirements of the machinery or raft supported.

6.9.3 Seatings are to be of substantial construction and efficiently supported by transverse and horizontal brackets or gusset plates. These should generally be arranged in line with plate floors and girders in a double bottom or with suitable deep beams or transverses and girders at upper decks. Where applicable, seats are to be designed to ensure proper alignment with gearing and allow for thermal expansion effects.

6.9.4 In general seats are not to be arranged in way of breaks or recesses in the bottom structure.

6.9.5 Main machinery or raft holding-down bolts are to be arranged as near as practicable to floors and longitudinal girders. When this cannot be achieved, additional floors are to be fitted.

6.9.6 Auxiliary machinery is to be secured on seating of adequate scantlings, so arranged as to distribute the loadings evenly into the supporting structure.

■ *Section 7*
Superstructures, deckhouses, bulwarks, sponsons and appendages

7.1 General

7.1.1 Superstructures, deckhouses, forecastles and bulwarks are to be constructed in accordance with the scantlings indicated in *Vol 1, Pt 6, Ch 3, 11 Superstructures, deckhouses and bulwarks*

7.1.2 For requirements relating to companionways, doors, accesses and skylights, *see Vol 1, Pt 3, Ch 4 Closing Arrangements and Outfit*

7.1.3 Requirements for machinery casings are given in *Vol 1, Pt 3, Ch 2, 6.7 Machinery casings*

7.1.4 For closing arrangements and outfit the requirements are given in *Vol 1, Pt 3, Ch 4 Closing Arrangements and Outfit*.

7.2 Definitions

7.2.1 The term ‘house’ is used to include both superstructures and deckhouses.

7.2.2 The lowest, or first tier of a house, is normally that which is directly situated on the deck to which *D*, is measured. The second tier is the next tier above the lowest tier and so on.

7.3 Structural requirements

7.3.1 The plating and supporting structure are to be suitably reinforced in way of localised areas of high stress such as corners of openings, cranes, masts, equipment, fittings and other heavy or vibrating loads.

7.3.2 Structures subject to concentrated loads are to be suitably reinforced. Where a concentration of loading on one side of a stiffener may occur, such as pillars out of line, the stiffener is to be adequately stiffened against torsion.

7.3.3 Primary stiffening members are to be continuous and substantially bracketed at their end connections to maintain continuity of structural strength.

7.3.4 Secondary stiffening members are to be effectively continuous and bracketed at their end connections as appropriate.

7.3.5 Transverse rigidity is to be maintained throughout the length of the house by means of web frames, bulkheads or partial bulkheads. Particular care is to be paid when an upper tier is wider than its supporting tier and when significant loads are carried on the house top.

7.3.6 Web frames or partial bulkheads are to be fitted in line with bulkheads or deep primary stiffeners below.

7.3.7 Special attention is to be given to the connection of the erection to the deck in order to provide an adequate load distribution and avoid stress concentrations. The house stiffening is to align with main hull stiffening wherever possible.

7.3.8 Where aluminium erections are arranged above a steel hull, details of the arrangements in way of the bimetallic connections are to be submitted.

7.3.9 Adequate support under the ends of houses is to be provided in the form of webs, pillars and diaphragms or bulkheads in conjunction with reinforced deck beams. At the corners of houses and in way of supporting structures attention is to be given to the connection to the decks and inserts or equivalent arrangements should generally be fitted.

7.4 Openings

7.4.1 All openings are to be substantially framed and have well rounded corners. Arrangements are to be made to minimise the effect of discontinuities in houses. Continuous coamings or girders are to be fitted below and above doors and similar openings. House tops are to be strengthened in way of davits and cranes.

7.4.2 Particular care is to be paid to the effectiveness of end bulkheads and the upper deck stiffening in way when large openings are fitted.

7.4.3 Special care is to be taken to minimise the size and number of openings in the sides or longitudinal bulkheads of houses which end within $0,25L_R$ to $0,75L_R$. Account is to be taken of the high vertical shear loading which can occur in these areas.

7.4.4 Windows, ventilators and other superstructure openings are to be suitably framed and mullions will in general be required.

7.5 Effective structure

7.5.1 For ships where L_R exceeds 40 m or for designs where the superstructure is designed to absorb global loads the effectiveness of superstructures to carry these loads is to be determined. The effectiveness may be assessed in accordance with *Vol 1, Pt 6, Ch 4, 2.5 Superstructures global strength*

7.5.2 When large openings or a large number of smaller openings are cut in the superstructure sides, reducing the capability to transmit shear force between decks, an assessment of structural efficiency may be required. The scantlings of the side structure in way of these areas may also be required to be increased.

7.6 Sponsons and appendages

7.6.1 Primary structure supporting sponsons is to be effectively integrated into the main hull structure. This is to be achieved by extending the primary framing system or by suitable scarfing the sponson primary structure over at least five frame spaces.

7.6.2 The scantlings of sponson structure are to be as required by the relevant parts of *Vol 1, Pt 6 Hull Construction in Steel*, for decks or side shell. Decks used for aircraft operations or wheeled vehicles are to comply with *Vol 1, Pt 4 Military Design and Special Features* and *Vol 1, Pt 6 Hull Construction in Steel* respectively.

7.6.3 Where sponsons are located outside of $0,4L_R$ amidships and extend outside of the waterline breadth, B_{WL}, of the ship the effects of wave impacts are to be considered. The loads are to be derived in accordance with the bow flare slamming requirements in *Vol 1, Pt 5, Ch 3, 3 Loads on shell envelope*

7.6.4 The strength and arrangement of large bilge keels, stabilisers and other protrusions that may impinge on icebergs or flows are to be specially considered. In some cases the speed for operation in ice may be restricted.

7.7 Unusual designs

7.7.1 Ships or structural arrangements which are of unusual design, form or proportions will be individually considered.

■ *Section 8*
Pillars and pillar bulkheads

8.1 General

8.1.1 Pillars and pillar bulkheads are to be constructed in accordance with the scantlings indicated in *Vol 1, Pt 6, Ch 3, 12 Pillars and pillar bulkheads*

8.1.2 Pillars are to be arranged to transmit loads from decks and superstructures into the bottom structure. Pillars are generally to be constructed from solid, tubular or I beam section. A pillar may be a fabricated trunk or partial bulkhead.

8.2 Head and heel connections

8.2.1 Pillars are to be attached at their heads to plates supported by efficient brackets, in order to transmit the load effectively. Doubling or insert plates are to be fitted to decks under large pillars and to the inner bottom under the heels of tubular or hollow square pillars. The pillars are to have a bearing fit and are to be attached to the head and heel plates by continuous welding. At the heads and heels of pillars built of rolled sections, the load is to be well distributed by means of longitudinal and transverse brackets.

8.3 Alignment and arrangement

8.3.1 Pillars are to be located on main structural members. They are in general to be fitted below windlasses, winches, capstans, the corners of deckhouses, large items of equipment and elsewhere where considered necessary.

8.3.2 Wherever possible, deck pillars are to be fitted in the same vertical line as pillars above and below, and effective arrangements are to be made to distribute the load at the heads and heels of all pillars.

8.3.3 Where pillars support eccentric loads, or are subjected to lateral pressures, they are to be suitably strengthened for the additional bending moment imposed upon them.

8.3.4 Doublers are generally to be fitted on decks and inner bottoms, other than within tanks where doublers are not allowed. Brackets or insert plates may be used instead of doublers.

8.3.5 In double bottoms under widely spaced pillars, the connections of the floors to the girders, and of the floors and girders to the inner bottom, are to be suitably increased. Where pillars are not directly above the intersection of plate floors and girders, partial floors and intercostals are to be fitted as necessary to support the pillars. Holes are not to be cut in the floors and girders below the heels of pillars. Where longitudinal framing is adopted in the double bottom, equivalent stiffening under the heels of pillars is to be provided, and where the heels of pillars are carried on a tunnel, suitable arrangements are to be made to support the load.

8.4 Pillars in tanks

8.4.1 In no circumstances are pillars to pass through tanks. Where loads are to be transmitted through tanks, pillars within the tanks are to be carefully aligned with the external pillars. The tensile stress in the pillar and its end connections is not to exceed 108 N/mm^2 at the tank test pressure. Such pillars are in general to be of built sections and end brackets may be required.

8.5 Fire aspects

8.5.1 Pillars and pillar bulkheads are to be suitably protected against fire, and capable of resisting fire damage. They are not to be constructed of aluminium.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter applies to all of the ships detailed in the Rules, and requirements are given for rudders, stabilisers, and appendages, nozzles, steering gear, bow and stern thrust unit structure and waterjet propulsion systems. For podded propulsion systems, *see Vol 2, Pt 4, Ch 4 Podded Propulsion Units*.

1.2 General

1.2.1 The following symbols and definitions are applicable to this Chapter, unless otherwise stated:

σ_o = minimum yield stress or 0,5 per cent proof stress of the material, in N/mm^2 and is not to be taken greater than 0,7σ_u or 450N/mm^2, whichever is the lesser

where

σ_u = ultimate tensile strength of the material, in N/mm^2

1.3 Navigation in ice

1.3.1 Where an ice class notation is to be included in the class of a ship, the requirements of *Vol 1, Pt 5, Ch 2, 4 Guidance for ice environment* are to be complied with.

1.4 Materials

1.4.1 The requirements for materials are contained in the *Rules for the Manufacture, Testing and Certification of Materials, July 2015* (hereinafter referred to as the Rules for Materials).

1.4.2 Rudder stocks, pintles, coupling flange bolts, keys and cast parts of rudders are assumed to be made of rolled, forged or cast carbon manganese steel in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2015*. Where other materials are proposed the scantlings will require to be specially considered on the basis of the Rules.

1.4.3 For rudder stocks, pintles, keys and bolts the minimum yield stress is not to be less than 200 N/mm^2. The following requirements are based on a material's yield stress of 235 N/mm^2. If material is used having a yield stress differing from 235 N/mm^2 the material factor is to be determined as follows:

$$K_o = \left[\frac{\sigma_o}{235}\right]^m$$

where

m = 0,75 for σ_o > 235 N/mm^2

m = 1,0 for $\sigma_o \leq$ 235 N/mm^2

σ_o is as defined in *Vol 1, Pt 3, Ch 3, 1.2 General 1.2.1*

1.4.4 In order to avoid excessive edge pressures in way of bearings, rudder stock deformations should be kept to a minimum. Where significant reductions in rudder stock diameter due to the application of steels with yield strengths exceeding 235 N/mm^2 are proposed, final acceptance may require the evaluation of the rudder stock deformations.

■ *Section 2* Rudders

2.1 General

2.1.1 The scantlings of the rudder stock are to be not less than those required by *Vol 1, Pt 3, Ch 3, 2.14 Rudder stock diameter in way of the tiller, dsu*, *Vol 1, Pt 3, Ch 3, 2.15 Rudder stock diameter ds* and *Vol 1, Pt 3, Ch 3, 2.16 Rudder stock (tubular)* as appropriate.

2.1.2 For rudders having an increased diameter of rudder stock, *see Figure 3.2.1 Rudder types*, the increased diameter is to be maintained to a point as far as practicable above the top of the lowest bearing. This diameter may then be tapered to the diameter required in way of the tiller. The length of the taper is to be at least three times the reduction in radius. Particular care is to be taken to avoid the formation of a notch at the upper end of the taper.

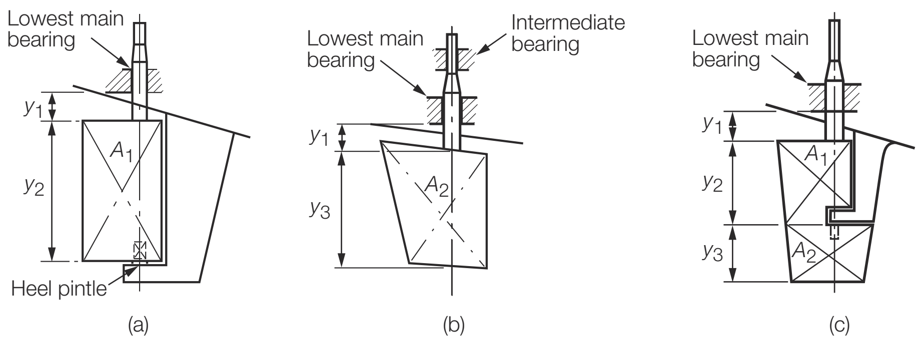


Figure 3.2.1 Rudder types

2.1.3 Sudden changes of section or sharp corners in way of the rudder coupling, jumping collars and shoulders for rudder carriers, are to be avoided.

2.2 Definition and symbols

2.2.1 Definitions and symbols for use throughout this Section are indicated in the appropriate Tables.

2.3 Direct calculations

2.3.1 Where the rudder is of a novel design, high aspect ratio or the speed of the ship exceeds 45 knots the scantlings of the rudder and rudder stock are to be determined by direct calculation methods incorporating model test results and structural analysis, where considered necessary by Lloyd's Register (hereinafter referred to as 'LR').

2.4 Equivalents

2.4.1 Alternative methods of determining the loads will be specially considered, provided that they are based on model tests, full scale measurements or generally accepted theories. In such cases, full details of the methods used are to be provided when plans are submitted for appraisal.

2.5 Rudder arrangements

2.5.1 Rudders considered are the types shown in *Figure 3.2.1 Rudder types*, of double plate or single plate construction, constructed from steel. Other rudder types and materials will be subject to special consideration.

2.6 Rudder profile coefficient, K_2

2.6.1 The rudder profile coefficient, K_2, for use in the determination of rudder force and rudder torque is to be as indicated in *Table 3.2.1 Rudder profile coefficient, K_2*.

Table 3.2.1 Rudder profile coefficient, K_2

Design criteria (*see Figure 3.2.2 Rudder profiles*)	K_2 ahead condition	K_2 astern condition
Normal profile	1,0	0,97
Hollow profile	1,25	1,12
High lift profile	1,7	To be specifically considered
Symbols K_2 = rudder profile coefficient for use in *Vol 1, Pt 3, Ch 3, 2.11 Rudder force, FR 2.11.1*		
Note Where a rudder is behind a fixed nozzle, the value of K_2, given above, is to be multiplied by 1,3.		

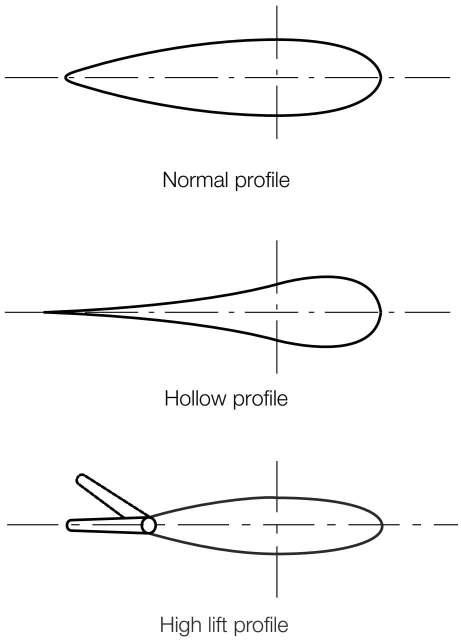


Figure 3.2.2 Rudder profiles

2.7 Rudder angle coefficient, K_3

2.7.1 The rudder angle coefficient, K_3, for use in the determination of rudder force and rudder torque is to be as indicated in *Table 3.2.2 Rudder angle coefficient, K_3*.

Table 3.2.2 Rudder angle coefficient, K_3

Rudder angle	2 x 35°	2 x 45°
K_3	1,0	1,23
Symbols		
K_3= rudder coefficient. Intermediate values may be obtained by interpolation.		

2.8 Rudder position coefficient, K_4

2.8.1 The rudder position coefficient, K_4, for use in the determination of rudder force and rudder torque is to be as indicated in *Table 3.2.3 Rudder position coefficient, K_4* .

Table 3.2.3 Rudder position coefficient, K_4

Design criteria		K_4
Ahead condition	Rudder out of propeller slipstream	0,8
	Rudder in propeller slipstream	1,0
	Rudder behind fixed propeller nozzle	1,15
Symbols		
K_4 = rudder position coefficient for use in *Vol 1, Pt 3, Ch 3, 2.11 Rudder force, FR 2.11.1*		

2.9 Rudder speed coefficient, K_5

2.9.1 The rudder speed coefficient, K_5, for use in the determination of rudder force and rudder torque is to be as indicated in *Table 3.2.4 Rudder speed coefficient, K_5* .

Table 3.2.4 Rudder speed coefficient, K_5

Design Criteria	K_5
Ships with $\frac{V}{\sqrt{L_{WL}}} < 3,0$	1,00
Ships with $\frac{V}{\sqrt{L_{WL}}} \geq 3,0$	$(1,12 - 0,005V)^3$
Symbols	
L_{WL} = as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars 5.2.1* V = as defined in *Vol 1, Pt 3, Ch 3, 2.11 Rudder force, FR* K_5 = rudder speed coefficient for use in *Vol 1, Pt 3, Ch 3, 2.11 Rudder force, FR 2.11.1*	

2.10 Centre of pressure

2.10.1 The position of the centre of pressure for use in the determination of the rudder torque is to be as indicated in *Table 3.2.5 Position of centre of pressure*.

Table 3.2.5 Position of centre of pressure

Design criteria	Value of x_{PF} and x_{PA}
Rectangular rudders; (a) Ahead condition (b) Astern condition	 x_{PF} = $(0{,}33e_h x_B - x_L)$, but not less than $0{,}12x_B$ x_{PA} = $(x_A - 0{,}25x_B)$, but not less than $0{,}12x_B$
Non-rectangular rudders; (a) Ahead condition(b) Astern condition	 x_{PF} and x_{PA} are to be calculated from geometric form (*see* note) but not less than: $\dfrac{0,12A_{\mathrm{R}}}{y_{\mathrm{R}}}$
Symbols	
x_{PF} =	horizontal distance from the centreline of the rudder pintles, or axle, to the centre of pressure in the ahead condition, in metres
x_{PA} =	horizontal distance from the centreline of the rudder pintles, or axle, to the centre of pressure in the astern condition, in metres
x_B =	breadth of rudder, in metres
y_R =	depth of rudder at centreline of stock, in metres
A_R =	rudder area, in m^2
x_L and x_A =	horizontal distances from leading and after edges, respectively, of the rudder to the centreline of the rudder pintles, or axle, in metres
x_S =	horizontal length of any rectangular strip of rudder geometric form, in metres
e_h =	hull form factor at ahead condition defined as follows:
=	for L < 65 m , e_h = 1,0
=	for $L \geq 65$ m
e_h =	$2\left(C_{\mathrm{b}} + 10\dfrac{B_{\mathrm{WL}}}{L_R} - 2\right)\dfrac{V}{\sqrt{L_{\mathrm{R}}}}$ but not less than 1,0 and need not be taken greater than
=	$1 + \left(\dfrac{L_{\mathrm{R}} - 65}{70}\right)$
L_R, B and C_b are as defined in *Vol 1, Pt 3, Ch 1, 5 Definitions*.V is as defined in *Vol 1, Pt 3, Ch 3, 2.11 Rudder force, FR 2.11.1*.	
Note For rectangular strips the centre of pressure is to be assumed to be located as follows: **Note** (a) $0{,}33e_h x_S$ abaft leading edge of strip for ahead condition. **Note** (b) $0{,}25x_S$ from aft edge of strip for astern condition.	

2.11 Rudder force, F_R

2.11.1 The rudder force, F_R, for use in the determination of the rudder scantlings is not to be taken less than that determined from the following formula:

$$F_R = 0{,}132\, K_1 K_2 K_3 K_4 K_5 A_R V^2 \text{ kN}$$

where

F_R = rudder force, in kN

K_1 = factor depending on the aspect ratio λ of the rudder area

= $\frac{(\lambda + 2)}{3}$ with λ is not to be taken greater than 2

λ = $\frac{h_r^2}{A_R}$ where h_r is mean height of the rudder area, in metres. Mean breadth and mean height of rudder are to be determined from *Figure 3.2.3 Rudder aspect ratio*

A_R = area of rudder blade, in m^2

K_2 = rudder profile coefficient, *see Table 3.2.1 Rudder profile coefficient, K_2*

K_3 = rudder angle coefficient, *see Table 3.2.2 Rudder angle coefficient, K_3*

K_4 = rudder position coefficient, *see Table 3.2.3 Rudder position coefficient, K_4*

K_5 = rudder speed coefficient, *see Table 3.2.4 Rudder speed coefficient, K_5*

V = maximum design speed for short term high power operations, in knots. When the speed is less than 8 knots, V is to be replaced by the expression:

= $V_{\min} = \frac{(V + 16)}{3}$ knots

For the astern condition the maximum astern speed, V_A, is to be used. $V_A \geq 0{,}5V$ knots.

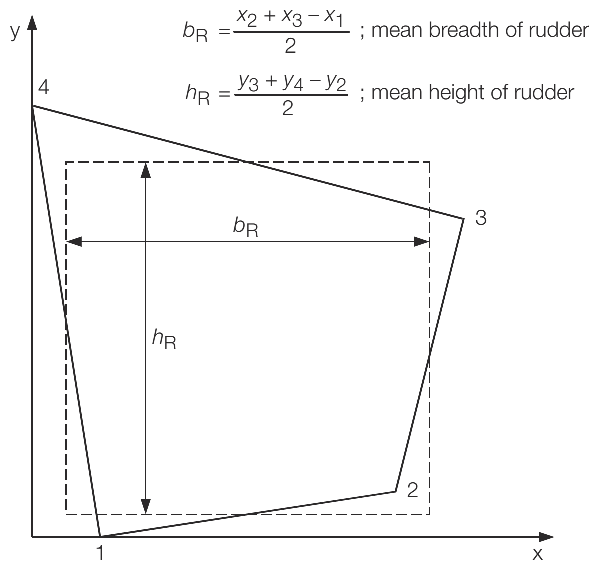


Figure 3.2.3 Rudder aspect ratio

2.12 Rudder torque, Q_R

2.12.1 The rudder torque, Q_R, for rudders without cut-outs in the ahead condition may be determined from the following formula:

$$Q_R = F_R x_{PF} \text{ kNm}$$

where

F_R = rudder force, in kN

x_{PF} = horizontal distance from the centreline of the rudder pintles or axle, to the centre of pressure in the ahead condition, in metres, *see Table 3.2.5 Position of centre of pressure*.

2.12.2 The rudder torque, Q_R, for rudders without cut-outs in the astern condition may be determined from the following formula:

$$Q_R = F_R x_{PA} \text{ kNm}$$

where

x_{PA} = horizontal distance from the centreline of the rudder pintles or axle, to the centre of pressure in the astern condition, in metres, *see Table 3.2.5 Position of centre of pressure*

F_R = rudder force, in kN

2.12.3 For rudders with cut-outs the rudder area, AR, used in the derivation of the rudder torque may be divided into two rectangular or trapezoidal parts with areas A_1 and A_2, so that $A_R = A_1 + A_2$, *see Figure 3.2.1 Rudder types*.

2.12.4 The rudder torque, Q_R, for rudders with cut-outs in the ahead condition may be determined from the following formula:

$$Q_R = Q_1 + Q_2 \text{ kNm}$$

= where

Q_1 = $F_{R1} x_{PF1}$ kNm

Q_2 = $F_{R2} x_{PF2}$ kNm

F_{R1} = $F_{RF} \dfrac{A_1}{A_R}$ kN

F_{R2} = $F_{RF} \dfrac{A_2}{A_R}$ kN

F_{RF} = rudder force in the ahead condition determined from *Vol 1, Pt 3, Ch 3, 2.2 Definition and symbols 2.2.1*, in kN

x_{PF1} = $b_{R1} (\alpha - k_1)$, in metres

x_{PF2} = $b_{R2} (\alpha - k_2)$, in metres

α = as given in Table 3.2.6 for the ahead condition

k_1 = $\dfrac{A_{1f}}{A_1}$

k_2 = $\dfrac{A_{2f}}{A_2}$

= A_{1f}, A_{2f} are shown in *Figure 3.2.4 Rudder areas*.

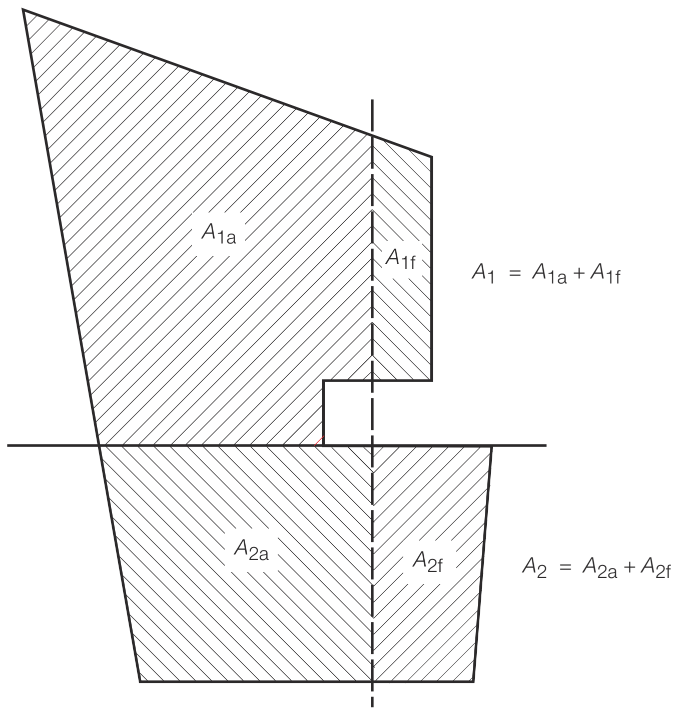


Figure 3.2.4 Rudder areas

2.12.5 The rudder torque, Q_R, for rudders with cut-outs in the astern condition may be determined from the following formula:

$Q_R = Q_1 + Q_2$ kNm

= where

$Q_1 = F_{R1}\, x_{PA1}$ kNm

$Q_2 = F_{R2}\, x_{PA2}$ kNm

$F_{R1} = F_{RA} \dfrac{A_1}{A_R}$ kN

$F_{R2} = F_{RA} \dfrac{A_2}{A_R}$ kN

F_{RA} = rudder force in the astern condition determined from *Vol 1, Pt 3, Ch 3, 2.2 Definition and symbols 2.2.1*, in kN

$x_{PA1} = b_{R1} (\alpha - k_1)$, in metres

$x_{PA2} = b_{R2} (\alpha - k_2)$, in metres

α = as given in Table 3.2.6 for the astern condition

$k_1 = \dfrac{A_{1f}}{A_1}$

$k_2 = \dfrac{A_{2f}}{A_2}$

= A_{1f}, A_{2f} are shown in *Figure 3.2.4 Rudder areas*.

Table 3.2.6 Coefficient, α

Condition	Behind fixed structure (*see* Note)	Not behind a fixed structure
Ahead	0,25	0,33
Astern	0,55	0,66
Note For rudder parts behind a fixed structure such as a rudder horn.		

2.13 Rudder bending moment, M_R

2.13.1 For spade rudders, Type (b) in *Figure 3.2.1 Rudder types*, the bending moment, M_R, may be determined from the following formula:

$$M_{\rm R} = F_{\rm R}\left(y_1 + \left(\frac{y_3(2x_1 + x_u)}{3(x_1 + x_u)}\right)\right) \text{kNm}$$

where

F_R is as given in *Vol 1, Pt 3, Ch 3, 2.11 Rudder force, FR 2.11.1*

y_1, y_3, x_l and x_u are rudder dimensions, in metres, *see Figure 3.2.5 Spade rudder*.

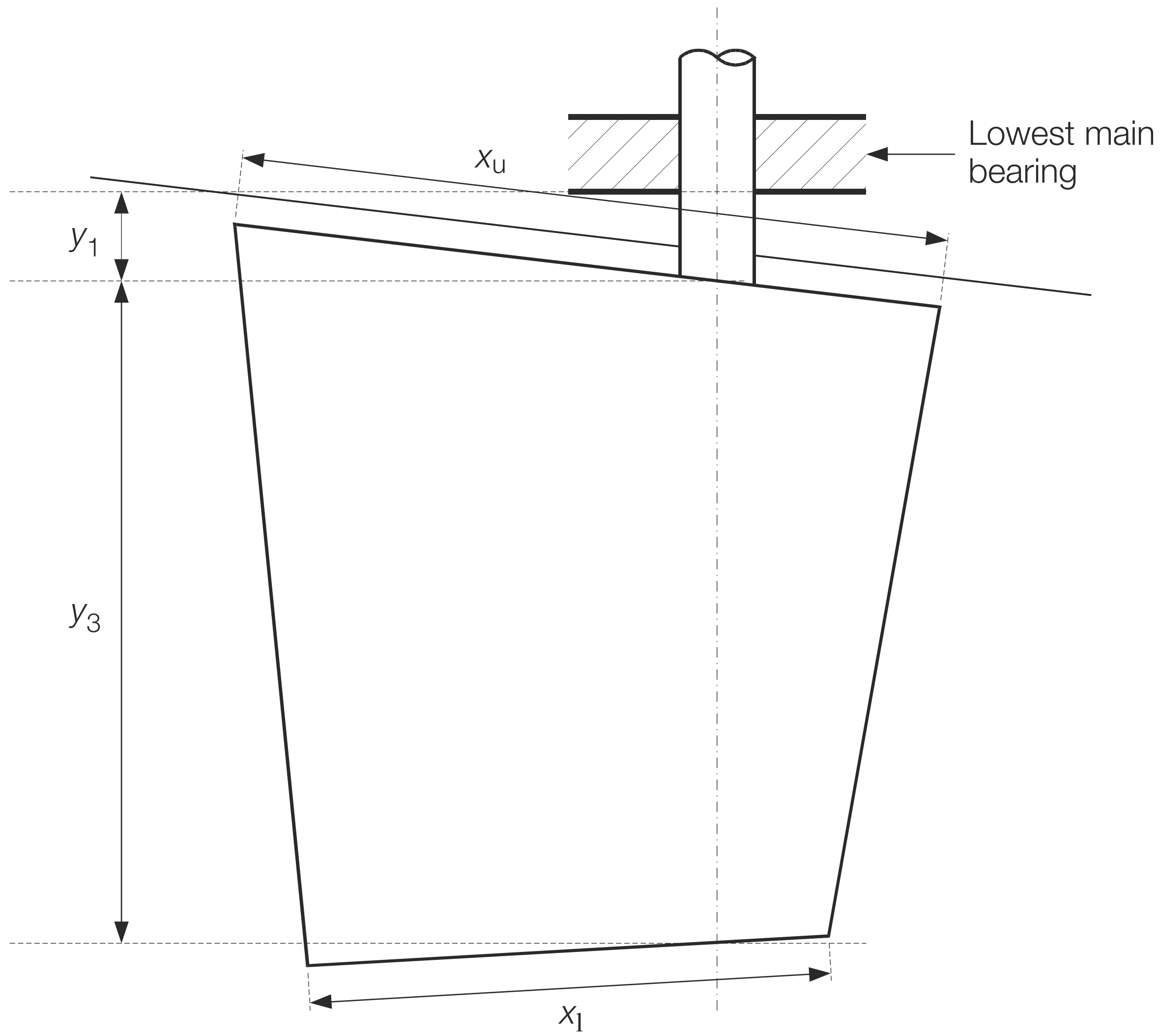


Figure 3.2.5 Spade rudder

2.13.2 For rudders supported by a rudder horn, Type (a) in *Figure 3.2.1 Rudder types*, the bending moment, M_R, may be determined from the following formula:

$$M_R = 0{,}125 F_R (y_1 + y_2) \text{ kNm}$$

where

F_R is as given in *Vol 1, Pt 3, Ch 3, 2.11 Rudder force, FR 2.11.1*

y_2 is a rudder dimension, in metres, *see Figure 3.2.6 Rudder supported by a rudder horn*

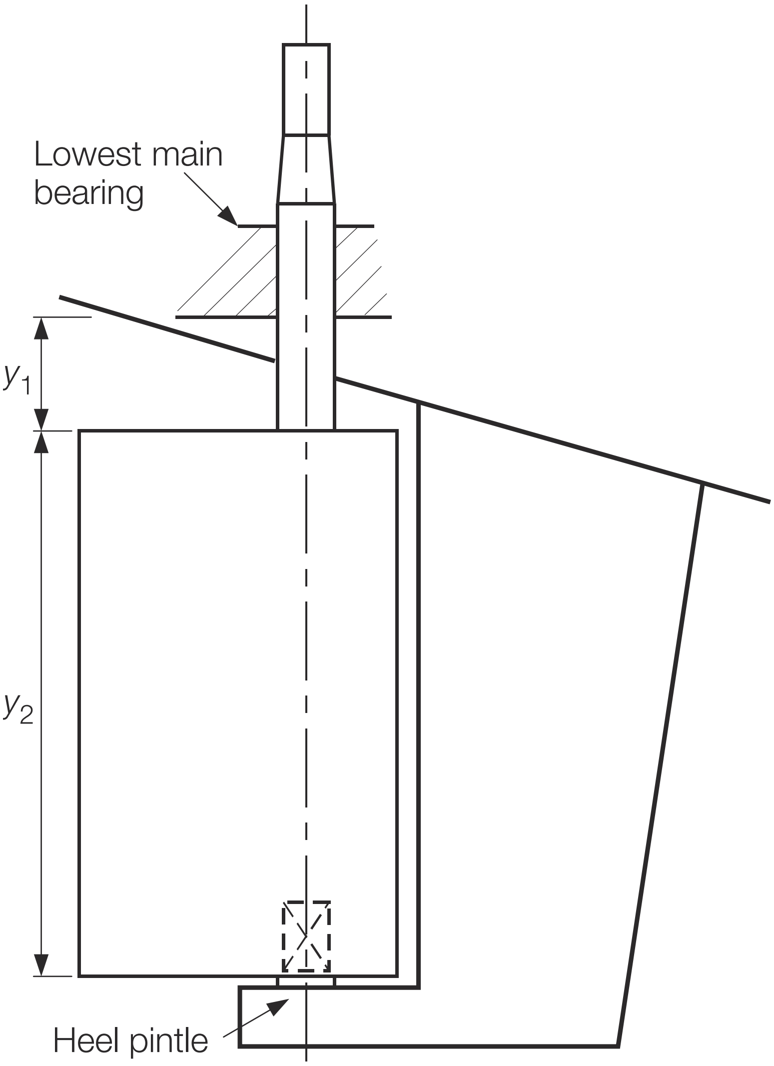


Figure 3.2.6 Rudder supported by a rudder horn

2.13.3 For semi-spade/mariner rudders, Type (c) in *Figure 3.2.1 Rudder types*, the bending moment, M_R, may be determined from the following formula:

$$M_{\mathrm{R}} = F_{\mathrm{R}} \frac{h_{\mathrm{R}}}{10\left(1 + \frac{b_{\mathrm{R}}}{A_{\mathrm{R}}}^{2}\right)} \text{ kNm}$$

FR = rudder force determined from *Vol 1, Pt 3, Ch 3, 2.2 Definition and symbols 2.2.1*, in kN

hR = mean height of rudder, in metres, *see Figure 3.2.3 Rudder aspect ratio*

bR = mean breadth of rudder, in metres, *see Figure 3.2.3 Rudder aspect ratio*.

2.14 Rudder stock diameter in way of the tiller, d_{su}

2.14.1 The torsional stress in the rudder stock, τ_t, in way of the tiller is not to exceed that determined from the following:

τ_t = $68K_o$ N/mm^2

2.14.2 The rudder stock diameter in way of the tiller, d_{su}, is to be not less than that determined from the formula:

$$d_{su} = 42\sqrt[3]{\frac{Q_R}{K_o}} \text{ mm}$$

where

Q_R = rudder torque (in the appropriate condition), in kNm, as given in *Vol 1, Pt 3, Ch 3, 2.12 Rudder torque, QR*

K_o = material factor, as defined in *Vol 1, Pt 3, Ch 3, 1.4 Materials 1.4.3*

2.15 Rudder stock diameter d_s

2.15.1 For a rudder stock subjected to combined torque and bending, the equivalent stress in the rudder stock is not to exceed that determined from the following:

σ_e = $118K_o$ N/mm^2

The equivalent stress is to be determined by the formula:

σ_e = $\sqrt{\sigma_b{}^2 + 3\tau_t{}^2}$ N/mm^2

where

Bending stress:

$$\sigma_b = 10200\frac{M_R}{d_s{}^3} \times 10^3 \text{ N/mm}^2$$

Torsional stress:

$$\sigma_t = 5100\frac{Q_R}{d_s{}^3} \times 10^3 \text{ N/mm}^2$$

2.15.2 The basic rudder stock diameter, d_s, at and below the lowest bearing is not to be less than that determined from the following:

$$d_s = d_{su}\sqrt[6]{1 + \frac{4}{3}\left(\frac{M_R}{Q_R}\right)^2} \text{mm}$$

where

d_{su} = diameter of the rudder stock in way of the tiller, in mm

M_R = rudder bending moment, kNm, *see Vol 1, Pt 3, Ch 3, 2.13 Rudder bending moment, MR*

Q_R = rudder torque (in the appropriate condition), in kNm, as given in *Vol 1, Pt 3, Ch 3, 2.12 Rudder torque, QR*.

2.16 Rudder stock (tubular)

2.16.1 Tubular rudder stock scantlings are to be not less than that necessary to provide the equivalent strength of a solid stock as required by *Vol 1, Pt 3, Ch 3, 2.14 Rudder stock diameter in way of the tiller, dsu 2.14.2* and *Vol 1, Pt 3, Ch 3, 2.15 Rudder stock diameter ds 2.15.2* as appropriate, and can be calculated from the following formula:

$$d_e = \sqrt[3]{\frac{d_1^{\,4} - d_2^{\,4}}{d_1}} \text{ mm}$$

where

d_e = the diameter of the equivalent solid rudder stock, in mm

d_1, d_2 = external and internal diameters, respectively of the tubular stock, in mm.

2.17 Single plate rudders

2.17.1 The scantlings of a single plate rudder are to be not less than required by *Table 3.2.7 Single plate rudder construction*.

Table 3.2.7 Single plate rudder construction

Item	Requirement
Blade thickness	t_B = 0,0015V s + 2,5 mm with a minimum of 10 mm
Arms	Spacing ≤ 1000mm Z_A = 0,0005V^2 x_a^2 s cm^3
Mainpiece	Diameter = d_s mm For spade rudders, the lower third may taper down to 0,75d_s mm
Symbols	
t_B = blade thickness, in mm s = vertical spacing of rudder arms/stiffeners, in mm V = speed, in knots, as defined in *Vol 1, Pt 3, Ch 3, 2.11 Rudder force, FR 2.11.1* x_a = horizontal distance from the aft edge of the rudder to the centre of the rudder stock, in metres Z_A = section modulus of arm, in cm^3 d_s = basic stock diameter, given by *Vol 1, Pt 3, Ch 3, 2.15 Rudder stock diameter ds 2.15.2*	

2.17.2 Rudder arms are to be efficiently attached to the mainpiece.

2.18 Double plate rudders

2.18.1 The scantlings of a double plated rudder are to be not less than required by *Table 3.2.8 Double plated rubber construction*.

Table 3.2.8 Double plated rubber construction

Item		Requirement
(1) Side plating		$t = 0{,}0224\, s\, \beta \sqrt{\dfrac{P_R}{110 K_o}} + 2{,}5$ mm
(2) Webs - vertical and horizontal		As (1) above
(3) Top and bottom plates		As (1) above using s = maximum rudder width, in mm, at top or bottom, but not less than 900 mm
(4) Nose plates		$t_N \geq 1{,}25t$ from (1) above
(5) Mainpiece – fabricated rectangular		Breadth and width $\geq d_s\ t_M = (8{,}5 + 0{,}56\ d_s)$ mm Minimum fore and aft extent of side plating = $0{,}2x_B$ Stress due to bending, *see* Table 3.2.9
(6) Mainpiece – tubular		Inside diameter $\geq d_s\ t_M$ as for (5) above Side plating as for (1) above Bending stress as for (5) above
(7) Testing	Pressure	2,45 m head and rudder should normally be tested while laid on its side
	Leak (air pressure)	0,02 N/mm^2 and arrangements made to ensure that no pressure in excess of 0,03 N/mm^2 can be applied

Symbols

β = $A_a (1 - 0{,}25 A_a)$

A_a = panel aspect ratio, but is not to be taken as greater than 2,0

t = thickness, in mm

s = spacing, in mm, of the webs, arms or stiffeners, but is not to exceed 900 mm

d_s = basic stock diameter, given by *Vol 1, Pt 3, Ch 3, 2.15 Rudder stock diameter ds 2.15.2*, in mm

t_N = thickness, in mm, of nose plate

t_M = thickness, in mm, of side plating and vertical webs forming mainpiece

x_B = breadth of rudder, in metres, on centreline of stock

P_R = rudder pressure

= $10T + \dfrac{F_R}{A_R}\ \mathrm{kN/m^2}$

T = is as detailed in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars 5.2.9*

F_R = rudder force, in kN, given by *Vol 1, Pt 3, Ch 3, 2.11 Rudder force, FR*

A_R = area of rudder blade, in m^2, given in *Vol 1, Pt 3, Ch 3, 2.11 Rudder force, FR 2.11.1*

Table 3.2.9 Bearing requirements

Item	Requirement	
Bearing Length	Depth Z_B, in mm $1,5d_s \geq Z_B \geq 1,0d_s$	
Main bearing wall thickness	The lesser of 0,2ds or 100 mm (*see* Note 1)	
Bearing pressure (on the projected area, where the projected area is to be taken as the length x diameter)	Bearing material	Maximum pressure, in N/mm^2 (*see* Note 2)
	MetalSynthetic	7,0 5,5
	Bearing material	Minimum clearance,in mm(*see* Note 3)
	Metal (*see* Note 4) Synthetic (*see* Note 5)	$0,001d_s$ + 1,0 $0,002d_s$ + 1,0but not less than 1,5
Symbols		
d_s = stock diameter, given by *Vol 1, Pt 3, Ch 3, 2.15 Rudder stock diameter ds 2.15.2*, in mm		
Note 1. Where web stiffening is fitted on the bearing, a reduction in wall thickness will be considered. Note 2. Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results. Note 3. Value of proposed minimum clearance is to be indicated on plans submitted for approval. Note 4. For bearings which are pressure lubricated the clearance must be restricted to enable the pressure to be maintained. Note 5. If non-metallic bearing material is applied, the bearing clearance is to be specially determined considering the material's swelling and thermal expansion properties. This clearance is not to be taken less than 1.5 on bearing diameter unless a smaller clearance is supported by the manufacturer's recommendation and there is documented evidence of satisfactory service history with a reduced clearance.		

2.18.2 In way of rudder couplings and heel pintles the plating thickness is to be suitably increased.

2.18.3 Adequate hand or access holes are to be arranged in the rudder plating in way of pintles as required and the rudder plating is to be reinforced locally in way of these openings. Continuity of the modulus of the rudder mainpiece is to be maintained in way of the openings.

2.18.4 Connection of rudder side plating to vertical and horizontal webs, where internal access for welding is not practicable, is to be by means of slot welds on to flat bars on the webs. The slots are to have a minimum length of 75 mm and in general, a minimum width of twice the side plating thickness. The ends of the slots are to be rounded. The space between the slots is not to exceed 150 mm and welding is to be based on a weld factor of 0,44.

2.18.5 On semi-spade/mariner type rudders the following items are to be complied with:

(a) The main vertical web forming the mainpiece is to be continuous over the full depth of the rudder.

(b) The thickness of the main vertical web is to be not less than two times the thickness required by *Table 3.2.8 Double plated rubber construction* from the top of the rudder to the lower pintle. The thickness is to be not less than required by *Table 3.2.8 Double plated rubber construction* from the lower pintle to approximately a point midway between the lower pintle and bottom of the rudder. Below this the thickness, t_2, is to be not less than the thickness required by *Table 3.2.8 Double plated rubber construction*. *See Figure 3.2.7 Main vertical web thickness*.

(c) Where an additional continuous main vertical web is arranged to form an efficient box mainpiece structure, the thickness of each web is to be not less than that required by *Table 3.2.8 Double plated rubber construction* from the top of the rudder to approximately a point midway between the lower pintle and bottom of the rudder. Below this the thickness, t_2, is not to be less than that required by *Table 3.2.8 Double plated rubber construction*.

(d) The internal radius, *r*, of the cut-out for the rudder pintle is to be as large as practicable. *See Figure 3.2.7 Main vertical web thickness*.

(e) To reduce the notch effect at the corners of the cut-out for the lower pintle, an insert plate 1,6 times the Rule thickness of the side plating is to be fitted. The insert plate is to extend aft of the main vertical web and to have well rounded corners.

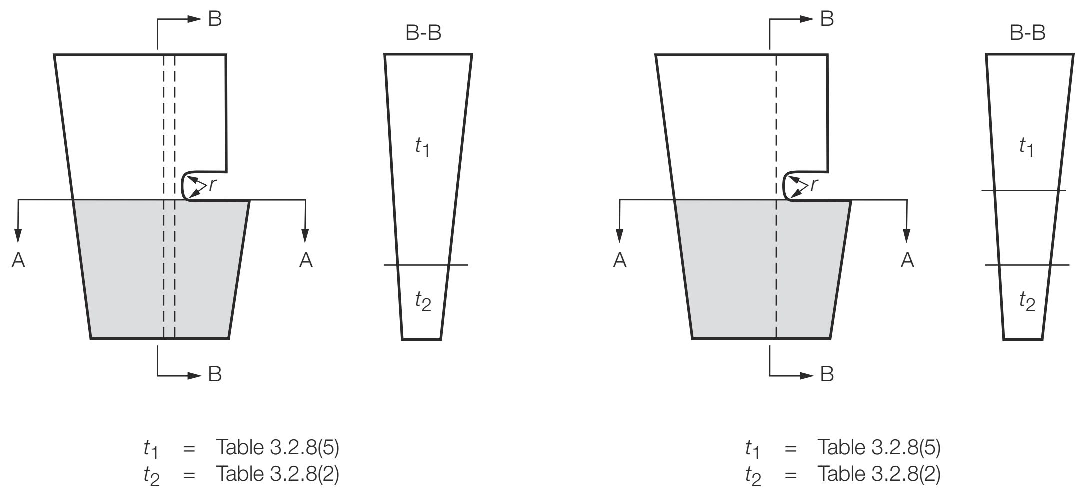


Figure 3.2.7 Main vertical web thickness

2.19 Cast metal rudders

2.19.1 Where rudders are cast, the mechanical and chemical properties of the metal are to be submitted for approval. If the rudder stock is cast integral with the rudder blade, abrupt changes of section and sharp corners are to be avoided.

2.20 Rudder stock and bearings

2.20.1 Bearings are to comply with the requirements of *Table 3.2.9 Bearing requirements*. The fitting of bearings is to be carried out in accordance with the manufacturer's recommendations to ensure that they remain secure under all foreseeable operating conditions.

Table 3.2.10 Permissible stresses for rudder blade scantlings

Item	Permissible stresses, in N/mm^2		
	Bending stress	Shear stress	Equivalent stress
Rudder blades clear of cut-outs, *see* Fig. 13.2.3	110K_0	50K_0	120K_0
Rudder blades in way of cut-outs, *see* Fig. 13.2.3 and Note	75K_0	50K_0	100K_0
Symbols			
K_0 is as defined in *Vol 1, Pt 3, Ch 3, 1.4 Materials 1.4.3*			
Note Requirements in way of cut-outs apply to semi-spade/mariner type rudders.			

2.21 Bearings

2.21.1 Bearings are to be of approved materials and effectively secured to prevent rotational and axial movement.

2.21.2 Synthetic rudder stock bearing materials are to be of a type approved by LR.

2.21.3 Where it is proposed to use stainless steel bearings for rudder stocks, the chemical composition is to be submitted for approval.

2.21.4 When stainless steel bearings are used, arrangements to ensure an adequate supply of sea-water to the bearing are to be provided.

2.21.5 When the rudder stock or liner is grade 316*L* austenitic stainless steel, it is recommended that gunmetal, lignum vitae or a synthetic bearing material be used in the bush. If a stainless steel is used in the bush, it is to be of a different grade and with an adequate hardness difference. The use of a ferritic/austenitic duplex structure stainless steel is recommended for the bush, but 17 per cent to 30 per cent chromium stainless steels are also suitable.

2.22 Liners

2.22.1 Where liners are fitted to rudder stocks or pintles, they are to be shrunk on or otherwise efficiently secured.

2.22.2 Where it is proposed to use stainless steel liners, the chemical composition is to be submitted for approval.

2.22.3 When stainless steel liners are used, arrangements to ensure an adequate supply of seawater to the liner are to be provided.

2.23 Pintles

2.23.1 Rudder pintles and their bearings are to comply with the requirements of *Table 3.2.11 Pintle requirements*.

Table 3.2.11 Pintle requirements

Item	Requirement	
(1) Pintle diameter (measured outside liner if fitted)	$d_{\text{PL}} = \sqrt{\left(\frac{235}{\sigma_{\text{o}}}\right)^{\text{m}}}\left(31 + 4,17V\sqrt{A_{\text{PL}}K_2}\right)$ mm For single pintle rudders and lower pintle of semi-spade rudders: $A_{\text{PL}} = \frac{A_{\text{R}}C_{\text{CP}}}{C_{\text{PL}}}$ m^2 but for semi-spade rudders need not be taken greater than A_{R}	
	Upper pintle on semi-spade rudders:	
	$A_{\text{PL}} = A_{\text{R}}\left(1 - \frac{C_{\text{CP}}}{C_{\text{PL}}}\right)$ m^2 or $0,35A_{\text{R}}$ m^2 whichever is greater	
(2) Maximum pintle taper	Method of assembly	Taper (on diameter)
	Manual assembly, key fitted (pintle ≤ 200 mm diameter) Manual assembly, key fitted (pintle ≥ 400 mm diameter)	1 in 6 1 in 9
	For keyed and other manually assembled pintles with diameters between 200mm and 400mm, the taper is to be obtained by interpolation.	
	Hydraulic assembly, dry fit	1 in 12
	Hydraulic assembly, oil injection	1 in 15
(3) Bearing length	$Z_{\text{PB}} \geq 1,2d_{\text{PL}}$ mmMay be less for very large pintles if bearing pressure is not greater than that given in (4), but Z_{PB} must be not less than $1,0d_{\text{PL}}$ mm	

(4) Bearing pressure (on projected area)	Bearing material	Pressure
	Metal	7,0 N/mm^2
	Synthetic	5,5 N/mm^2
	Using force acting on bearing: $P_{PL} = \frac{A_{PL} F_R}{A_R}$ kN A_{PL} as for item (1) A_R and F_R are as defined in *Vol 1, Pt 3, Ch 3, 2.11 Rudder force, FR 2.11.1*	
(5) Gudgeon thickness in way of pintle (measured outside bush if fitted)	$b_G \geq 0{,}5 d_{PL}$ but need not normally exceed 125 mm	
(6) Pintle clearance (note should be taken of the manufacturer's recommended clearances particularly where bush material requires pre-soaking). Value of proposed minimum clearance is to be indicated on plans submitted for approval.	Bearing material	Minimum clearance, mm
	Metal	$0{,}001 d_{PL} + 1{,}0$
	Synthetic	$0{,}002 d_{PL} + 1{,}0$ but not less than 1,5

Symbols

d_{PL} = pintle diameter, in mm

V = as defined in *Vol 1, Pt 3, Ch 3, 2.11 Rudder force, FR 2.11.1* but not less than 10 knots

A_{PL} = rudder area supported by the pintle, in m^2

C_{CP}, C_{PL} = dimensions in metres, as indicated in *Figure 3.2.8 Lower pintle housed above rudder gudgeon*

A_R = rudder area, in m^2

σ_o = as defined in *Vol 1, Pt 3, Ch 3, 1.2 General 1.2.1*

Z_{PB} = pintle bearing length, in mm

P_{PL} = force acting on bearing, in kN

b_G = thickness of gudgeon material in way of pintle, in mm

m = as defined in *Vol 1, Pt 3, Ch 3, 1.4 Materials 1.4.3*

K_2 = rudder profile coefficient, as given in *Table 3.2.1 Rudder profile coefficient, K_2*

Note Proposals for higher pressures or other materials will be specially considered on the basis of satisfactory test results.

2.23.2 Where the lower pintle is housed above the rudder gudgeon, *see Figure 3.2.8 Lower pintle housed above rudder gudgeon*, C_{PL} is to be measured to the top of the gudgeon.

2.23.3 Special attention is to be paid to the fit of the pintle taper into its socket. To facilitate removal of the pintles, it is recommended that the taper is to be not less than half the maximum value given in *Table 3.2.11 Pintle requirements*.

2.23.4 The distance between the lowest rudder stock bearing and the upper pintle is to be as short as possible.

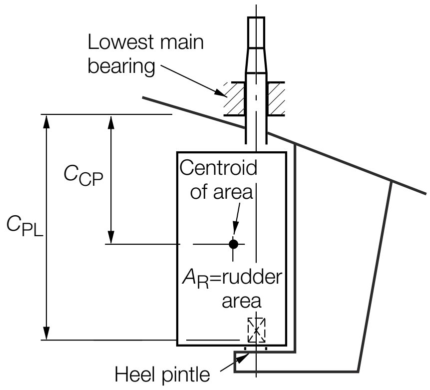


Figure 3.2.8 Lower pintle housed above rudder gudgeon

2.23.5 Where liners are fitted to pintles, they are to be shrunk on or otherwise efficiently secured. If liners are to be shrunk on, the shrinkage allowance is to be indicated on the plans. Where liners are formed by stainless steel weld deposit, the pintles are to be of weldable quality steel and details of the procedure are to be submitted.

2.23.6 Where an ***IWS** (In-water Survey) notation is to be assigned, *see Vol 1, Pt 3, Ch 3, 2.40 In-water Survey requirements* .

2.23.7 The bottom pintle on semi-spade (Mariner) type rudders are:

(a) if inserted into their sockets from below, to be keyed to the rudder or sternframe as appropriate or to be hydraulically assembled, with the nut adequately locked, or
(b) if inserted into their sockets from above, to be provided with an appropriate locking device, the nut being adequately secured.

2.24 Bolted couplings

2.24.1 Rudder coupling design is to be in accordance with *Table 3.2.12 Rudder couplings to stock* .

2.24.2 Where coupling bolts are required they are to be fitted bolts. Suitable arrangements are to be made to lock the nuts.

2.24.3 For rudders with horizontal coupling arrangements the rudder stock should be forged when the stock diameter exceeds 350 mm. Where the stock diameter does not exceed 350 mm the rudder stock may be either forged or fabricated. Where the upper flange is welded to the rudder stock, a full penetration weld is required and its integrity is to be confirmed by non-destructive examination. The flange material is to be from the same welding materials group as the stock. Such rudder stocks are to be subjected to a furnace post-weld heat treatment (PWHT) after completion of all welding operations. For carbon or carbon manganese steels, the PWHT temperature is not to be less than 600°C.

2.24.4 For a spade rudder the fillet radius between the rudder stock and the flange is to conform to the requirements of *Figure 3.2.9 Rudder stock horizontal flange fillet radius for spade rudders*. Where space permits between the upper face of the flange and the lower rudder stock bearing, it is preferable to use a compound fillet design of the parabolic or Morgenbrod form having similar dimensions to those of *Figure 3.2.9 Rudder stock horizontal flange fillet radius for spade rudders*. Alternative arrangements will be specially considered.

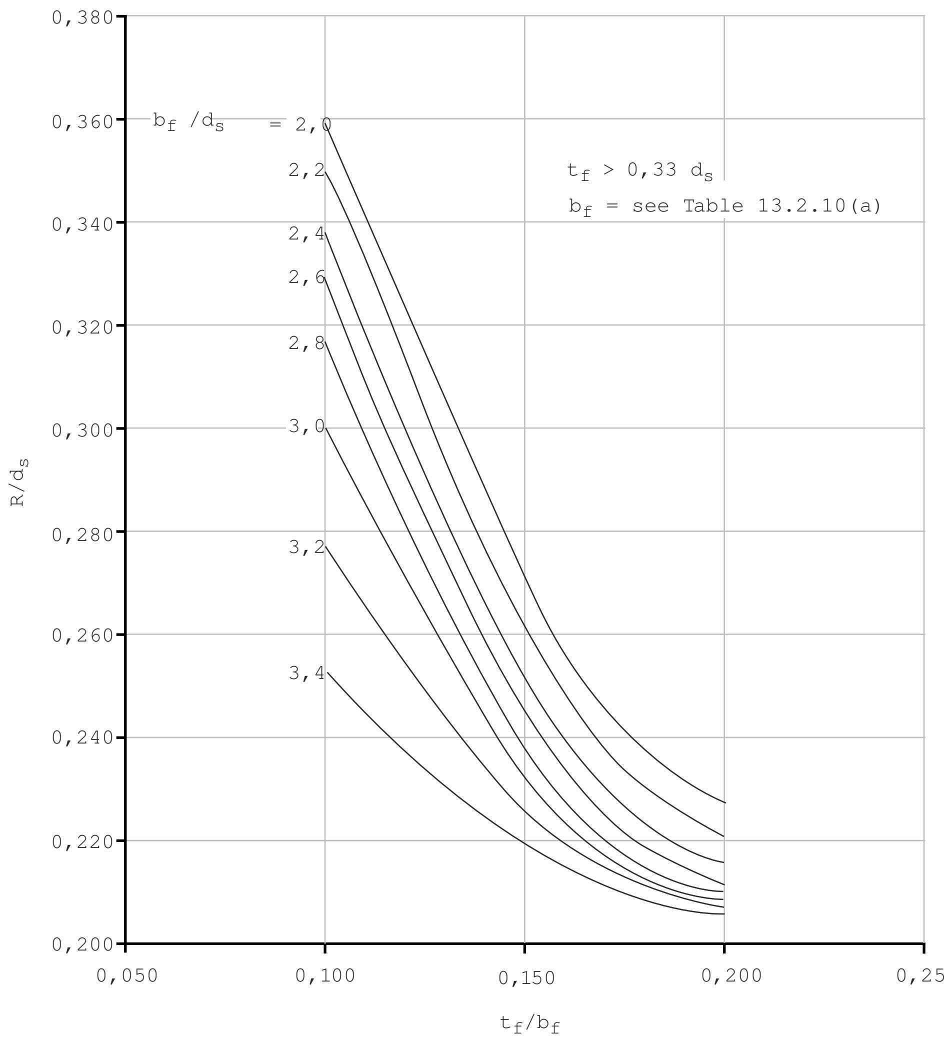


Figure 3.2.9 Rudder stock horizontal flange fillet radius for spade rudders

2.24.5 The connecting bolts for coupling the rudder to the rudder stock are to be positioned with sufficient clearance to allow the fitting and removal of the bolts and nuts without contacting the palm radius, *R*, *see Figure 3.2.10 Rudder stock connection*. The surface forming the palm radius is to be free of hard and sharp corners and is to be machined smooth to the Surveyor's satisfaction. The surface in way of bolts and nuts is to be machined smooth to the Surveyor's satisfaction.

2.24.6 For spade rudders fitted with a fabricated rectangular mainpiece, the mainpiece is to be designed with its forward and aft transverse sections at equal distances forward and aft of the rudder stock transverse axis, *see Figure 3.2.10 Rudder stock connection*.

Table 3.2.12 Rudder couplings to stock

Arrangement	Parameter	Requirement	
		Horizontal coupling	Vertical coupling

(1)	Bolted couplings (*see* note 4)	n	≥6	≥8
		d_b	$\dfrac{0,65 d_s}{\sqrt{n}}$	$\dfrac{0,81 d_s}{\sqrt{n}}$
		m	$0,00071 n\, d_s\, d_b^{\,2}$	$0,00043 d_s^{\,3}$
		t_f	$\geq d_b$	d_b
		α_{max} (*see* Note 2)	$\left(53,82 - \dfrac{35,29}{K_o}\right)\dfrac{d_s^{\,3}}{F_R h 10^6} - \left(1,8 - 6,3\dfrac{R}{d_s}\right)\dfrac{t_f - t_{fa}}{t_{fa}}$	–
		$\alpha_{as\ built}$ (*see* Note 2)	$\leq \alpha_{max}$	–
		w_f	$0,67 d_b$	$0,67 d_b$
(2)	Conical couplings	θ_t	$\leq \dfrac{1}{K_1}$	
		l_t	$\geq 1.5 d_s$	
		σ_{GM}	$\dfrac{P_R\,\theta_t d_{STM} + 4Q_R\sqrt{K_2\left(\left(\dfrac{P_R d_{STM}}{2Q_R}\right)^2 + 1\right) - \left(\dfrac{\theta_t}{2}\right)^2}}{5,66\left(d_{STM}\right)^2 l_t\left(K_2 - \left(\dfrac{\theta_t}{2}\right)^2\right)}$	
		w	$\dfrac{9,6\,\sigma_{GM} d_{STM}}{\theta_t\left(1 - f_m^{\,2}\right)} \times 10^{-6}$	
		P_u	Approximately equal to	$2,83\,\sigma_{GM} l_t d_{STM}\left(K_3 + \dfrac{\theta_t}{2}\right)$
		P_o	Approximately equal to	$2,83\,\sigma_{GM} l_t d_{STM}\left(K_3 - \dfrac{\theta_t}{2}\right)$
		σ_o	$\geq \dfrac{12,35 \times 10^4 w\,\theta_t\sqrt{3 + f^4}}{d_{ST}}$	
Symbols				

n = number of bolts in coupling

d_b = diameter of coupling bolts, in mm

d_s, d_{su} = rudder stock diameters as defined in *Vol 1, Pt 3, Ch 3, 2.15 Rudder stock diameter ds* and *Vol 1, Pt 3, Ch 3, 2.14 Rudder stock diameter in way of the tiller, dsu* respectively

m = first moment of area of bolts about centre of coupling, in cm^3

t_f = thickness of coupling flange, in mm

w_f = width of flange material outside the bolt holes, in mm

K_o = rudder stock material factor *see Vol 1, Pt 3, Ch 3, 1.4 Materials 1.4.3*

h = vertical distance between the centre of pressure and the centre point of the palm radius, R, in metres, *see Figure 3.2.10 Rudder stock connection*

R = palm radius between rudder stock and connected flange not smaller than $\frac{d_s}{10}$ in mm

t_f = minimum thickness of coupling flange, in mm

t_{fa} = as built flange thickness, in mm

α_{max} = maximum allowable stress concentration factor

$\alpha_{as\ built}$ = stress concentration factor for as built scantlings

$$= \frac{0,73}{\sqrt{\left(\frac{R}{d_s}\right)}}$$

θ_t = taper of conical coupling, on the diameter, e.g.:

$$= \theta_t = \frac{1}{15} = 0,067$$

F_R = rudder force kN

l_t = length of taper, in mm

σ_{GM} = required mean grip stress, in N/mm^2

w = corresponding push-up of rudder stock, in mm

P_u, P_o = corresponding push-up, pull-off loads respectively, in N

σ_o = minimum yield stress of stock and gudgeon material, in N/mm^2. σ_o is not to be taken greater than 70% of the ultimate tensile strength

P_R = effective weight of rudder, in N

d_{STM} = mean diameter of coupling taper, in mm

d_{ST} = diameter of coupling taper at any position, in mm

d_{GHM} = mean external diameter of gudgeon housing, in mm

d_{GH} = external diameter of gudgeon housing at any position, in mm

f_m = $\frac{d_{STM}}{d_{GHM}}$

f = $\frac{d_{ST}}{d_{GH}}$

Q_R = maximum turning moment applied to stock, and is to be taken as the greater of:

(a) = As determined from *Vol 1, Pt 3, Ch 3, 2.12 Rudder torque, QR*.

(b) = The torque generated by the steering gear at the maximum working pressure

b_f = breadth of the flange, in mm

K_1, K_2, K_3 = constants depending on the type of assembly adopted as follows:

		K_1	K_2	K_3
Oil injection method	with key	15	0,0064	0,025
	without key	15	0,0036	0,025

Dry fit method	with key	12	0,0128	0,170
	without key	12	0,0072	0,170

Note 1. Where materials vary for individual components, scantling calculations for such components are to be based on d_s for the relevant material.

Note 2. For spade rudders with horizontal coupling, t_f is not to be less than 0,33d_s. The mating plate on the rudder is to have the same thickness as the flange on the stock d_s.

Note 3. For a twin spade rudder arrangement with single screw where the rudders are within the slipstream of the propeller: (a) the thickness of the palm is not to be less than 0,35 d_s . (b) where the stock is welded to the palm plate, the stock diameter, d_s is to be increased by 14%.

Note 4. This requirement is applicable only for spade rudders with horizontal couplings, *see Figure 3.2.10 Rudder stock connection*

2.25 Conical couplings

2.25.1 Where a rudder stock is connected to a rudder by a keyless fitting, the rudder is to be a good fit on the rudder stock cone. During the fit-up, and before the push-up load is applied, an area of contact of at least 90 per cent of the theoretical area of contact is to be achieved and this is to be evenly distributed. The relationship of the rudder to stock at which this occurs is to be marked and the push-up then measured from that point. The upper edge of the upper mainpiece bore is to have a slight radius. After final fitting of the stock to the rudder, positive means are to be used for locking the securing nut to the stock.

2.25.2 Where a keyed tapered fitting of a rudder stock to a rudder is proposed, a securing nut of adequate proportions is to be provided. After final fitting of the stock to the rudder, positive means are to be used for locking this nut.

2.26 Rudder carrier arrangements

2.26.1 The weight of the rudder is to be supported at the heel pintle or by a carrier attached to the rudder head. The hull structure supporting the carrier bearing is to be adequately strengthened. The plating under all rudder-head bearings or rudder carriers is to be increased in thickness.

2.27 Anti-jump collars

2.27.1 Suitable arrangements are to be provided to prevent the rudder from lifting.

2.27.2 Jumping collars are not to be welded to the rudder stock.

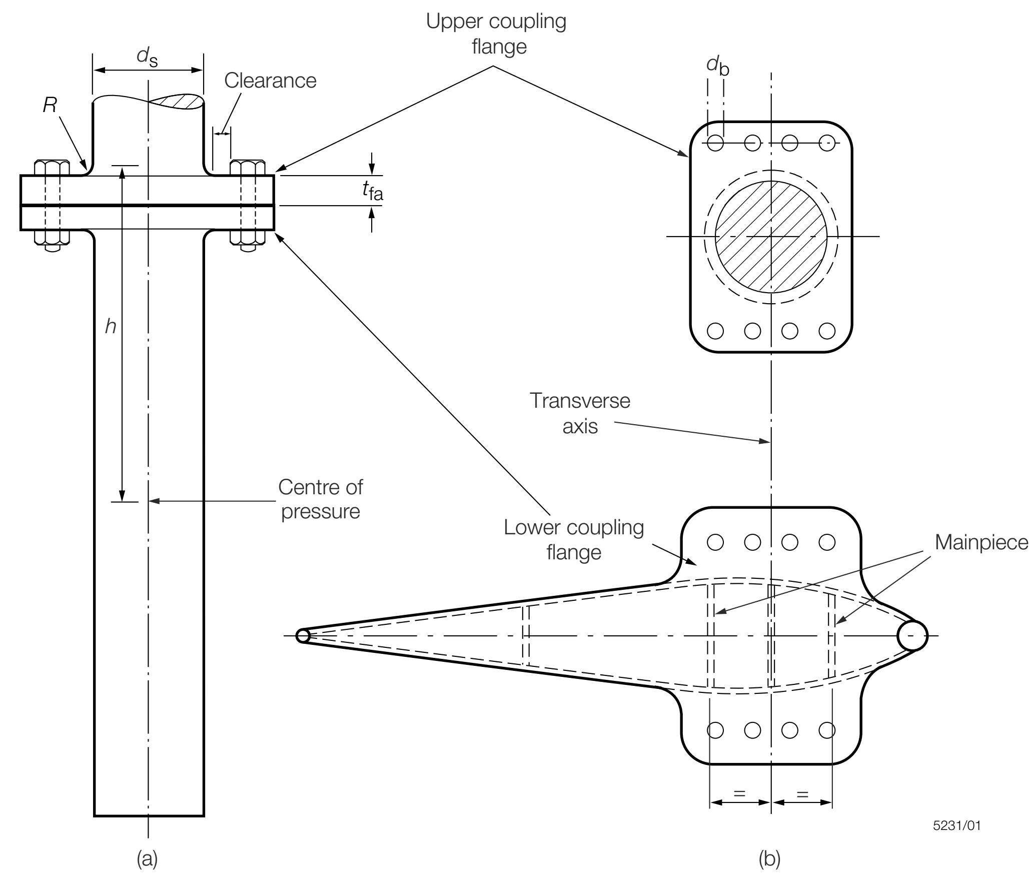


Figure 3.2.10 Rudder stock connection

2.28 Drain plugs

2.28.1 Where rudders are of plated construction, drain plugs are to be provided to ensure that all compartments can be adequately drained. These plugs are to be locked and details of their scantlings, arrangements and position clearly indicated on the rudder plan.

2.29 Corrosion protection

2.29.1 All metalwork is to be suitably protected against corrosion. This may be by coating or, where applicable, by a system of cathodic protection.

2.29.2 Metalwork is to be suitably cleaned before the application of any coating. Where appropriate, blast cleaning or other equally effective means is to be employed for this purpose.

2.30 Dissimilar materials

2.30.1 Where materials vary for individual components, they are to be compatible to avoid galvanic corrosion. Scantling calculations for the components are to be based on d_s for the relevant material, *see Vol 1, Pt 3, Ch 3, 2.15 Rudder stock diameter ds*

2.31 Internal coatings

2.31.1 Internal surfaces of the rudder are to be efficiently coated or the rudder is to be filled with foam plastics. Where it is intended to fill the rudder with plastic foam, details of the foam are to be submitted for consideration.

2.32 Pressure testing

2.32.1 For testing of rudders, *see Vol 1, Pt 6 Hull Construction in Steel*

2.33 Tiller arms, quadrants

2.33.1 Tillers and quadrants are to comply with the requirements of *Vol 2, Pt 6, Ch 1 Steering Gear*.

2.33.2 The steering gear is to be mounted on a seat and adequately secured.

2.34 Connecting bars

2.34.1 Connecting bars are to comply with the requirements of *Vol 1, Pt 6, Ch 1 General*.

2.35 Keys and keyways

2.35.1 Where the tiller or quadrant is bolted, a key having an effective cross-sectional area in shear of not less than $0{,}25d_{su}$ mm^2 is to be fitted. The thickness of the key is to be not less than $d_{su}/6$ mm. Alternatively, the rudder stock may be machined to a square section in lieu of fitting a key. d_{su} is as defined in *Vol 1, Pt 3, Ch 3, 2.14 Rudder stock diameter in way of the tiller, dsu*.

2.35.2 Keyways are to extend over the full depth of the tiller boss.

2.35.3 Keyways in the rudder stock are to have rounded ends and the corners at the base of the keyway are to be radiused.

2.36 Stopping arrangements

2.36.1 Suitable rudder stops are to be provided to limit the rudder angle to the desired level port and starboard. These stops are to be of substantial construction and efficiently connected to the supporting structure.

2.37 Novel designs

2.37.1 Where rudders are of a novel design they may be specially considered on the basis of the Rules. Alternatively, the calculations are to be submitted for consideration.

2.38 Rudder tube arrangements

2.38.1 The rudder tube construction is to be of steel.

2.38.2 The scantlings of rudder tubes will be individually considered.

2.38.3 The bottom shell in way of the rudder tubes is to be additionally reinforced by means of an insert plate to increase the bottom shell thickness by 50 per cent.

2.38.4 Where rudder tubes are to be retained by bolting they are to be provided with a substantial flange securely attached to the hull structure. Where bolts are used, the nuts are to be suitably locked.

2.38.5 Where rudder tubes are to be welded to hull insert plates full penetration welding is required.

2.38.6 Rudder tubes are to be supported by suitable brackets and deep floors to avoid hard spots on the shell and to ensure continuity of the main hull structure.

2.38.7 Rudder bearings are to be secured against rotation within the rudder tubes by suitable pinch bolting or keys. Details are to be submitted for approval.

2.39 Watertight gland

2.39.1 In rudder trunks which are open to the sea, a seal or stuffing box is to be fitted above the deepest load waterline to prevent water from entering the steering gear compartment and the lubricant from being washed away from the rudder carrier. If the top of the rudder trunk is below the deepest waterline two separate stuffing boxes are to be provided. Rudder trunk boundaries where exposed to the sea are to have a corrosion protection coating applied in accordance with the manufacturer's instructions.

2.39.2 Where the top of the rudder tube is significantly higher than the deepest load waterline, a lesser arrangement of watertightness such as 'O' rings may be accepted.

2.39.3 The watertight gland body may be formed by the top of the fabricated or cast rudder tube, the gland packing being retained against the top bearing or a check in the wall of the rudder tube, and is compressed by a gland packet which may be of the flange type, screwed cap or other suitable arrangement.

2.39.4 Alternative arrangements utilising lip seals or 'O' rings either in isolation or in combination with one or other of the alternative seal arrangements will be the subject of special consideration.

2.40 In-water Survey requirements

2.40.1 Where in-water surveys are required, notation is to be assigned, (*see Vol 1, Pt 1, Ch 2, 4.5 Existing ships – Periodical Surveys 4.5.5*), means are to be provided for ascertaining the rudder pintle and bush clearances and for verifying the security of the pintles in their sockets with the ship afloat.

■ *Section 3* Stabiliser arrangements

3.1 General

3.1.1 This section details the requirements for fin stabilisers, stabiliser tanks and bilge keel and fins.

3.1.2 The effectiveness of the fin stabilisers are outwith the scope of classification; however their scantlings, arrangements, foundations, supporting structure and watertight integrity are to be examined.

3.1.3 Engineering systems are to comply with the appropriate requirements indicated in *Vol 2 Machinery and Engineering Systems*, as applicable.

3.1.4 The general structure of the fin stabiliser is to comply with the Rule requirements for rudders.

3.1.5 Fin stabilisers are to be contained between watertight bulkheads.

3.1.6 For non-retractable type stabilisers, the watertight bulkheads forming the forward and aft extent of the compartment are to be arranged not less than one third of the root chord length, *C*, from the fore and aft most extents of the stabiliser, *see Figure 3.3.1 Stabiliser positioning*. This requirement exists in order to ensure limited flooding in the event of hull damage in way of the fin. Alternate arrangements which are considered to be equivalent to the Rule requirements will be accepted.

3.1.7 For retractable type stabilisers, the watertight bulkheads forming the forward and aft extent of the compartment are to be arranged not less than the total length of the stabiliser (measured from the extreme end of the shaft to the blade tip) from the centreline of the stabiliser shaft.

3.1.8 For non-retractable type stabilisers, a separate watertight box surrounding the shell entry point may be required if the stabiliser is located adjacent to a critical compartment. No stabiliser box is needed if the compartment which it is in has adequate pumping arrangements and the ship has at least a one-compartment flooded damage capability.

3.1.9 Where a watertight box surrounding the shell entry point is required, it is to extend longitudinally not less than the minimum bulkhead positions defined in *Vol 1, Pt 3, Ch 3, 3.1 General 3.1.6* and vertically to ensure complete enclosure of the machinery and allow adequate inspection, *see Figure 3.3.1 Stabiliser positioning*.

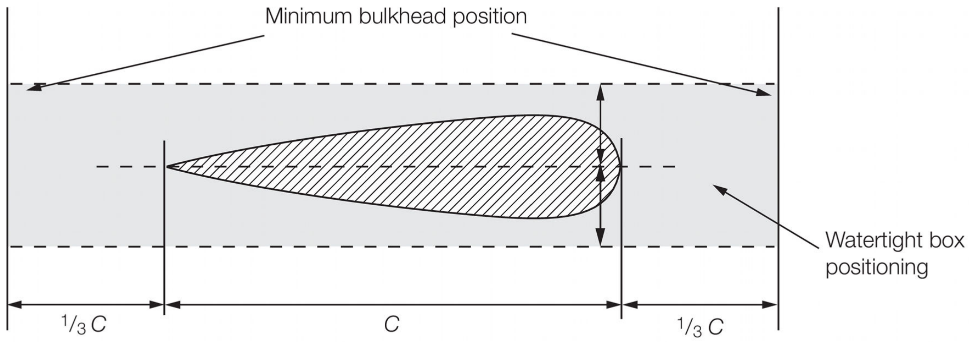


Figure 3.3.1 Stabiliser positioning

3.1.10 For both retractable and non-retractable type stabilisers the compartment in which the stabilisers are fitted is to contain a water ingress detector and alarm.

3.1.11 Fin stabiliser systems are, in general, not to extend beyond the extreme waterline breadth, B_{WL}, of the hull or below the horizontal line of keel. However, for retractable fins, alternative arrangements may be specially considered. Where the stabiliser fin extends beyond the extreme moulded beam of the hull in the active mode, the side shell is to be permanently marked indicating the fore and aft extent of the stabiliser, when deployed. It is recommended that an appropriate symbol be placed on the hull side between the marks.

3.1.12 The shell plating in way of retractable stabilisers is to comply with the requirements of *Vol 1, Pt 3, Ch 3, 3.2 Fin stabilisers*. However, the longitudinal extent of the insert is to be such that it extends beyond around the hull opening in the fore/aft direction by not less than 25 per cent of the root chord length of the foil. In all other directions the extent of the insert shall be 1,25 times the root chord length of the foil over all operational lengths.

3.1.13 The scantlings of internal watertight bulkheads and stiffening for fixed installations are to be specified by the designer/ Builder and/or fin unit manufacturer, but in no case are to be less than the scantlings for double bottoms as defined in *Vol 1, Pt 6, Ch 3 Scantling Determination*. Suitable access is to be provided to allow for maintenance and inspection purposes.

3.1.14 The scantlings and sealing arrangements for the pedestal and bearings will be specially considered, subject to the designer/Builder submitting the following:

(a) Detailed structural calculations for the proposed foundation and adjacent supporting structure.
(b) A detailed finite element analysis, if carried out.
(c) Calculations demonstrating that the effect of damage to the stabiliser arrangement arising from the high speed impact, grounding, fouling, etc. will not compromise the structural and watertight integrity of the ship.
(d) Maximum torque, bending moments and bearing loads expected for the proposed design.
(e) The stabiliser fin stock material, together with its ultimate tensile shear strength values (N/mm^2).

3.1.15 Fin bearing materials are to be of an approved type.

3.1.16 Where retractable stabilisers are fitted, position indicators are to be provided on the bridge and at auxiliary steering positions.

3.1.17 Where the fin stabiliser is of a novel design, high aspect ratio or the speed of the ship exceeds 45 knots, and the anticipated loads are likely to be significant, the scantlings of the fin and fin stock are to be determined by direct calculation methods incorporating model test results and structural analysis, where considered necessary by LR.

3.2 Fin stabilisers

3.2.1 The stabiliser machinery and surrounding structure is to be adequately supported and stiffened. Where cyclic bending stresses are induced in the structure which are likely to reduce the fatigue life the maximum stress is not to exceed 39,0 N/mm^2 in mild steel. Where other materials are used for the supporting structure the limiting stress values will be specially considered.

3.2.2 The fin box into which the stabilisers are fitted is to have a perimeter plating with thickness not less than the surrounding Rule shell plating plus 2 mm, and is to be stiffened to the same standard as the adjacent hull structure. Ships constructed from materials other than steel will be specially considered.

3.2.3 Insert plates are to be fitted in way of stabilisers. The thickness of the insert is to be at least 50 per cent greater than the bottom shell thickness in way and is to extend over an area 1,25 times the stabiliser root chord length, covering all operational angles. In addition, for retractable stabilisers, the insert is to extend beyond the shell opening for a distance of not less than 25 per cent of the length of the root chord.

3.2.4 The thickness of plating in way of retractable foil recesses is to be not less than the bottom shell thickness plus 2 mm. Internal stiffening is to comply with the requirements of *Vol 1, Pt 3, Ch 3 Ship Control Systems*,*Vol 1, Pt 3, Ch 4 Closing Arrangements and Outfit*, as applicable.

3.3 Centre of pressure

3.3.1 The position of the centre of pressure for use in the determination of the fin torque is to be as indicated in *Table 3.3.1 Position of centre of pressure*.

Table 3.3.1 Position of centre of pressure

Design criteria	Value of x_{PF} and x_{PA}
Rectangular fins:	
(a) Ahead condition	$x_{PF} = (0{,}33x_B - x_L)$, but not less than $0{,}12x_B$
(b) Astern condition	$x_{PA} = (x_A - 0{,}25x_B)$, but not less than $0{,}12x_B$
Non-rectangular fins:	
(a) Ahead condition	x_{PF} as calculated from geometric form
(b) Astern condition	x_{PA} (*see* note) but not less than: $\dfrac{0,12A_F}{Y_F}$
Symbols	
x_{PF} = horizontal distance from the centreline of the fin stock, to the centre of pressure in the ahead condition, in metres	
x_{PA} = horizontal distance from the centreline of the fin stock, to the centre of pressure in the astern condition, in metres	
x_B = breadth of fin, in metres	
y_F = depth of fin at centreline of stock, in metres	
A_F = fin area, in m^2	
x_L and x_A = horizontal distances from leading and after edges, respectively, of the fin to the centreline of the fin stock, in metres	
x_S = horizontal length of any rectangular strip of fin geometric form, in metres	
Note For rectangular strips the centre of pressure is to be assumed to be located as follows:	
Note (a) $0{,}33x_S$ abaft leading edge of strip for ahead condition.	
Note (b) $0{,}25x_S$ from aft edge of strip for astern condition.	

3.4 Fin force, F_F

3.4.1 The fin force, F_F , in kN, for use in the determination of the fin scantlings is to be submitted. For the astern condition the maximum astern speed, V_A, is to be used. In no case is the astern speed to be taken less than that determined from the following: $V_A \geq 0{,}5V$ knots.

3.5 Fin torque, Q_F

3.5.1 The fin torque, Q_F, for the ahead condition may be determined from the following formula:

$$Q_F = F_F x_{PF} \text{ kNm}$$

where

x_{PF} = horizontal distance from the centreline of the fin stock, to the centre of pressure in the ahead condition, in metres, *see Table 3.3.1 Position of centre of pressure*

F_F = fin force as defined in *Vol 1, Pt 3, Ch 3, 3.4 Fin force, FF 3.4.1*.

3.5.2 The fin torque, Q_F, for the astern condition may be determined from the following formula:

$$Q_F = F_F x_{PA} \text{ kNm}$$

where

x_{PA} = horizontal distance from the centreline of the fin stock, to the centre of pressure in the astern condition, in metres, *see Table 3.3.1 Position of centre of pressure*

F_F = fin force as defined in *Vol 1, Pt 3, Ch 3, 3.4 Fin force, FF 3.4.1*

3.6 Fin bending moment, M_F

3.6.1 For conventional fins the bending moment, M_F, may be determined from the following formula:

$$M_F = F_F\left(y_1 + \left(\frac{y_2(2x_1 + x_u)}{3(x_1 + x_u)}\right)\right) \text{kNm}$$

where

F_F is as given in *Vol 1, Pt 3, Ch 3, 4 Rudder horns and appendages*

y_1, y_3, x_1 and x_u are fin dimensions, in metres

see Figure 3.3.2 Fin stabiliser

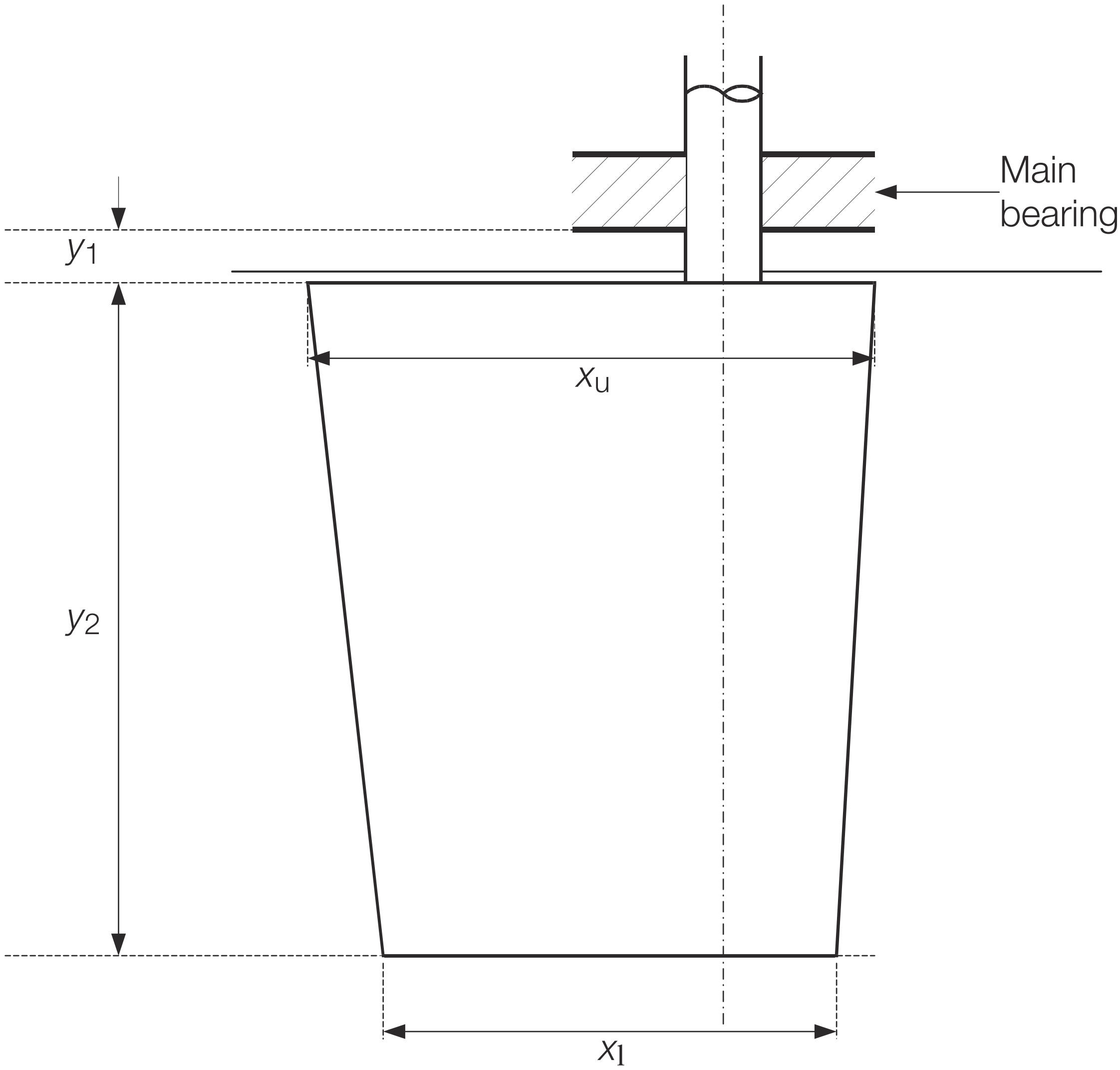


Figure 3.3.2 Fin stabiliser

3.7 Fin stock diameter in way of tiller, d_{Fu}

3.7.1 The fin stock diameter in way of the tiller, d_{Fu}, is to be not less than that determined from the formula:

$$d_{FU} = 42\sqrt[3]{\frac{Q_F}{K_o}}\ \text{mm}$$

where

Q_F = fin torque (in the appropriate condition), in kNm, as given in 3,5

K_o = material factor, as defined in *Vol 1, Pt 3, Ch 3, 1.4 Materials 1.4.3*

3.8 Fin stock diameter, d_F

3.8.1 For a fin stock subjected to combined torque and bending, the equivalent stress in the fin stock is not to exceed that determined from the following:

= $\sigma_e \leq 118 K_o$ N/mm²

where

K_o = material factor, as defined in *Vol 1, Pt 3, Ch 3, 1.4 Materials 1.4.3*.

The equivalent stress is to be determined by the formula:

$$\sigma_e = \sqrt{\sigma_b^2 + 3\tau_t^2}\ \mathrm{N/mm^2}$$

Bending stress: = $\sigma_b = 10200 \dfrac{M_F}{d_F^3} \times 10^3\ \mathrm{N/mm^2}$

Torsional stress: = $\tau_t = 5100 \dfrac{Q_R}{d_F^3} \times 10^3\ \mathrm{N/mm^2}$

3.8.2 The basic fin stock diameter, d_F, at and below the lowest bearing is not to be less than that determined from the following:

$$d_F = d_{Fu} \sqrt[6]{1 + \frac{4}{3}\left(\frac{M_F}{Q_F}\right)^2}\ \mathrm{mm}$$

where

d_{Fu} = diameter of the fin stock in way of the tiller, in mm

M_F = fin bending moment, kNm, *see Vol 1, Pt 3, Ch 3, 3.6 Fin bending moment, MF*

Q_F = fin torque (in the appropriate condition), in kNm, as given in *Vol 1, Pt 3, Ch 3, 3.5 Fin torque, QF*

3.9 Fin plating

3.9.1 The thickness of the fin side plating is not to be less than that determined from the following:

t = $0{,}0224\, s\, \beta \sqrt{\dfrac{P_F}{110 K_o}} + 2{,}5$ mm

where

s = stiffener spacing, in mm

β = panel aspect ratio correction factor

= $A_R (1 - 0{,}25 A_R)$ for $A_R \leq 2$

= 1 for $A_R > 2$

A_R = panel aspect ratio

= panel length/panel breadth

P_F = fin pressure, in kN/m²

= $10T + \dfrac{F_F}{A_F}$ kN/mm²

T = maximum draught, in metres

F_F = fin force, in kN, *see Vol 1, Pt 3, Ch 3, 3.4 Fin force, FF*

A_F = fin area, in m^2

K_o = material factor, as defined in *Vol 1, Pt 3, Ch 3, 1.4 Materials 1.4.3*.

3.9.2 The thickness of the nose plates is not to be less than 1,25 times the thickness of the fin side plating. The thickness of web plates is not to be less than 70 per cent of the thickness of the fin side plating, or 6 mm, whichever is the greater.

3.9.3 Alternative materials and methods for fin stabilisers will be specially considered.

3.10 Stabiliser tanks

3.10.1 The general structure of the tank is to comply with the Rule requirements for deep tanks. Sloshing forces in the tank structure are to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

3.11 Bilge keels and fins

3.11.1 It is recommended that bilge keels are not fitted forward of 0,7L_R on ships intended to navigate in ice conditions.

3.11.2 Bilge keels are to be gradually tapered at the ends and arranged to finish in way of a suitable internal stiffening member. The taper is to have a length to depth ratio of at least three to one.

3.11.3 A plan of the bilge keels is to be submitted for approval of material grades, welded connections and detail design.

3.11.4 The scantlings and attachment to the hull plating for steel ships is to be in accordance with *Vol 1, Pt 6, Ch 6, 5.11 Bilge keels and ground bars*.

3.12 Novel features

3.12.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised standards and good practice, and are to be submitted for consideration.

■ *Section 4* Rudder horns and appendages

4.1 General

4.1.1 Rudder horns and boss end brackets may be constructed of cast or forged steel or fabricated from steel plate. Where shaft brackets are fitted these may be either fabricated, cast or forged from steel.

4.1.2 In castings, sudden changes of section or possible constrictions to the flow of metal during casting are to be avoided. All fillets are to have adequate radii, which, in general, are to be not less than 50 to 75 mm, depending on the size of the casting.

4.1.3 Castings and forgings are to comply with the requirements of *Ch 4 Steel Castings*and *Ch 5 Steel Forgings* of the Rules for Materials.

4.1.4 Rudder horns, shaft brackets, etc. are to be effectively integrated into the ship structure, and their design is to be such as to facilitate this.

4.2 Propeller boss

4.2.1 The thickness of the propeller boss is to be not less than:

$$0,1d_{\mathrm{TS}} + 56\ butneednotexceed\ 0,3d_{\mathrm{TS}}$$

where

d_{TS} = diameter of tailshaft in mm, *see Figure 3.4.1 Propeller boss*.

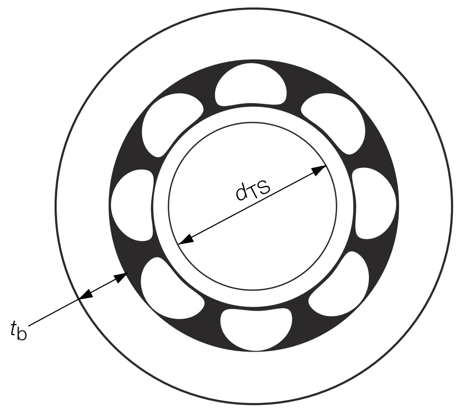


Figure 3.4.1 Propeller boss

4.3 Rudder horns

4.3.1 The requirements for the scantlings and arrangements of rudder horns will be subject to special consideration and may require to be determined by direct calculations.

4.4 Shaft bossing

4.4.1 Where the propeller shafting is enclosed in bossings extending back to the bearings supporting the propellers, the aft end of the bossings and the bearings are to be supported by substantially constructed boss end castings or fabrications. These are to be designed to transmit the loading from the shafting efficiently into the ship's internal structure.

4.4.2 For shaft bossings attached to shaft brackets, the length of the boss is to be adequate to accommodate the aftermost bearing and to allow for proper connection of the shaft brackets.

4.4.3 Cast steel supports are to be suitably radiused where they enter the main hull to line up with the boss plating radius. Where the hull sections are narrow, the two arms are generally to be connected to each other within the ship. The arms are to be strengthened at intervals by webs.

4.4.4 Fabricated supports are to be carefully designed to avoid or reduce the effect of hard spots. Continuity of the arms into the ship is to be maintained, and they are to be attached to substantial floor plates or other structure. The connection of the arms to the bearing boss is to be by full penetration welding.

4.4.5 The scantlings of supports will be specially considered. In the case of certain high powered ships, direct calculations may be required.

4.4.6 The boss plating is generally to be radiused into the shell plating and supported at the aft end by diaphragms at every frame. These diaphragms are to be suitably stiffened and connected to floors or a suitable arrangement of main and deep web frames. At the forward end, the main frames may be shaped to fit the bossing, but deep webs are generally to be fitted not more than four frame spaces apart.

4.5 Shaft brackets

4.5.1 The scantlings of the arms of shaft brackets, based on a breadth to thickness ratio of about five, are to be determined from *Vol 1, Pt 3, Ch 3, 4.6 Single arm shaft brackets ('P' – brackets) 4.6.1* or *Vol 1, Pt 3, Ch 3, 4.7 Double arm shaft brackets ('A' – brackets) 4.7.2* as appropriate.

4.5.2 Where the propeller shafting is exposed to the sea for some distance clear of the main hull, it is generally to be supported adjacent to the propeller by independent brackets having two arms. In very small ships the use of single arm brackets will be considered.

4.5.3 Fabricated brackets are to be designed to avoid or reduce the effect of hard spots and ensure a satisfactory connection to the hull structure. The connection of the arms to the bearing boss is to be by full penetration welding.

4.5.4 Bracket arms are in general to be carried through the shell plating, they are to be attached to floors or girders of increased thickness. The shell plating is to be increased in thickness and connected to the arms by full penetration welding.

4.5.5 In the case of certain high powered ships direct calculations may be required.

4.5.6 For shaft brackets having hollow section arms, the cross-sectional areas at the root and the boss should be not less than that required for a solid arm which satisfies the Rule section modulus having the proportions stated in *Vol 1, Pt 3, Ch 3, 4.5 Shaft brackets 4.5.1*.

4.5.7 The length of the shaft bracket boss, l_b, is to be sufficient to support the length of the required bearing. In general, l_b is not to be less than $4d_t$, where d_t is the Rule diameter of the screwshaft, in mm, *see Vol 2, Pt 3, Ch 2, 4.4 Screwshafts and tube shafts*. Proposals for a reduction in the required shaft bracket boss length will be considered in conjunction with details of the bearing material, allowable bearing operating pressure and installation arrangements, *see Vol 2, Pt 3, Ch 2, 4.16 Sternbushes and sterntube arrangements 4.16.2*. However, in no case is l_b to be less than the greater of:

(a) $2d_t$;
(b) that recommended by the bearing manufacturer;
(c) as required by *Vol 1, Pt 3, Ch 3, 4.4 Shaft bossing 4.4.2*.

4.5.8 Where the shaft and the shaft bracket boss are of the same material, the thickness of the shaft bracket boss is not to be less than $d_t/4$. Where the shaft and the shaft bracket boss are of dissimilar materials, the thickness of the boss, t_b, is to be not less than:

$$t_b = 0,75 d_t \left(\sqrt[3]{f_1} - 0,667 \right) \text{mm}$$

Note In no case is t_b to be taken as less than 12 mm

where

d_t = Rule diameter of the screwshaft, in the appropriate screwshaft material, in mm

f_1 = σ_S/σ_B but not less than 0,825

σ_S = ultimate tensile strength of the shaft material, in N/mm^2

σ_B = ultimate tensile strength of the boss material, in N/mm^2

4.5.9 The design of the shaft brackets with regard to disturbance of the hydrodynamic flow into the propeller and rudders is outwith the scope of classification

4.6 Single arm shaft brackets (‘P’ – brackets)

4.6.1 Single arm shaft brackets are to have a section modulus, Z_{xx}, at the palm of not less than that determined from the formula:

$$Z_{xx} = \frac{a_s d_{up}^2 f}{45000} \text{ cm}^3$$

where

a_s = the length of the arm to be measured from the centre of the section at the palm to the centreline of the shaft boss, in mm, *see Figure 3.4.2 Single arm shaft bracket (bolted attachment)*

d_{up} = the Rule diameter for an unprotected screwshaft, in mm, as given in*Vol 2, Pt 3, Ch 2 Shafting Systems* using A = 1,0

f = $400/\sigma_u$

σ_u = ultimate tensile strength of arm material, in N/mm^2

The cross-sectional area of the bracket at the boss is to be not less than 60 per cent of the area of the bracket at the palm.

4.6.2 For single arm shaft brackets a vibration analysis may be required if deemed necessary by LR.

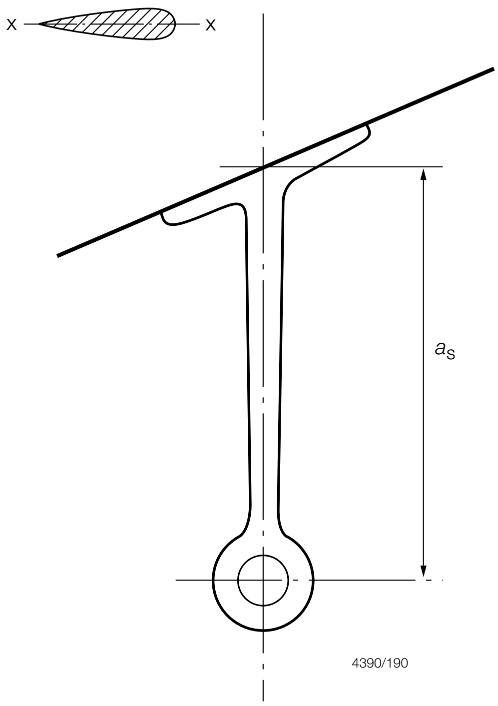


Figure 3.4.2 Single arm shaft bracket (bolted attachment)

4.7 Double arm shaft brackets ('A' – brackets)

4.7.1 The angle between the arms for double arm shaft brackets is to be generally not less than 50°. Proposals for the angle between the arms to be less than 50° will be specially considered with supporting calculations to be submitted by the designers.

4.7.2 The arms of double arm shaft brackets are to have a section modulus, Z_{xx}, of not less than that determined from the formula:

$$Z_{xx} = 0{,}45\, n^3 \text{ cm}^3$$

where

n = the minimum thickness, in cm, of a hydrofoil section obtained from:

$$n = d_{up} \sqrt{\left(\frac{f}{2000}\right)\left(1 + \sqrt{\left(1 + \left(1 + \frac{0{,}0112}{f}\right)\left(\frac{a_d}{d_{up}}\right)^2\right)}\right)} \text{ cm}$$

a_d = the length of the longer strut, in mm, *see Figure 3.4.3 Double arm shaft bracket (bolted attachment)*

d_{up} and f are as given in *Vol 1, Pt 3, Ch 3, 4.6 Single arm shaft brackets ('P' – brackets) 4.6.1*

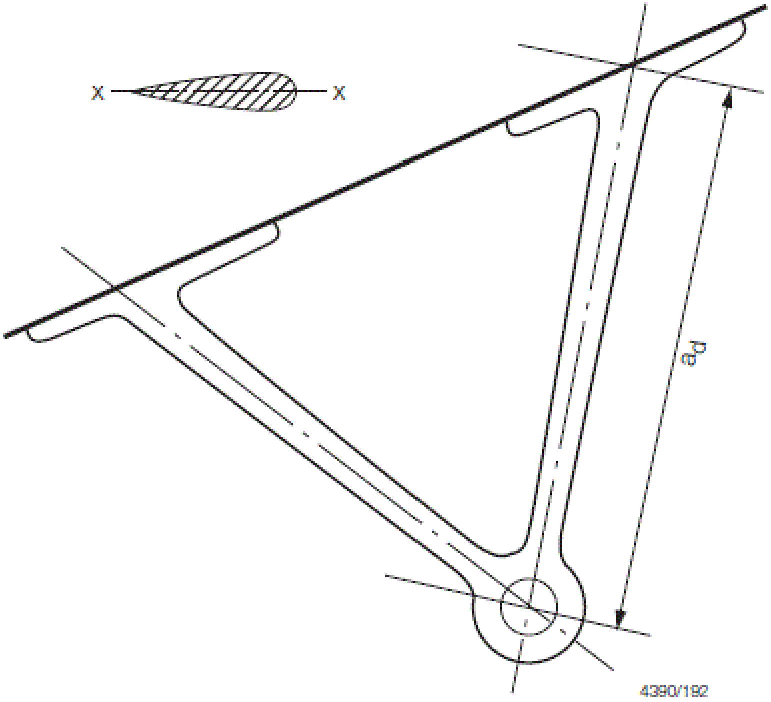


Figure 3.4.3 Double arm shaft bracket (bolted attachment)

4.8 Intermediate shaft brackets

4.8.1 The length and thickness of the shaft bracket boss are to be as required by *Vol 1, Pt 3, Ch 3, 4.5 Shaft brackets 4.5.7* or *Vol 1, Pt 3, Ch 3, 4.5 Shaft brackets 4.5.8* as appropriate. The scantlings of the arms will be specially considered on the basis of the Rules.

4.9 Attachment of shaft brackets by welding

4.9.1 Fabricated supports are to be carefully designed to avoid or reduce the effect of hard spots. Continuity of the arms into the ship is to be maintained, and they are to be attached to substantial floor plates or other structure. The connection of the arms to the bearing boss is to be by full penetration welding.

4.10 Attachment of shaft brackets by bolting

4.10.1 The bottom shell thickness in way of the double arm propeller bracket palms is to be increased by 50 per cent. The bottom shell thickness in way of single arm propeller brackets palms is to be doubled in thickness. The insert plates are to be additionally supported by substantial floor plates or other structure.

4.10.2 Where shaft brackets are attached by bolts, they are to be provided with substantial palms securely attached to the hull structure which is to be adequately stiffened in way. Where bolts are used, the nuts are to be suitably locked.

4.10.3 The bracket palms may be bolted directly onto the shell using a suitable bedding compound. The palms may be bolted onto suitable shims or chocking compound, of an approved type, to facilitate alignment.

4.10.4 Where brackets are bolted onto resin chocks, plans indicating the following information are to be submitted for approval:

(a) The thrust and torque loads, where applicable, that will be applied to the chocked item.
(b) The torque load to be applied to the bracket mounting bolts.
(c) The material of the bracket mounting bolts.
(d) The number, thread size, shank diameter and length of the mounting bolts.

4.10.5 The minimum thickness of a resin chock is to be 12 mm.

4.10.6 The bracket palms are to have well radiused corners, and the faying surface to be dressed smooth. The palm thickness in way of the bolts is to be not less than the propeller bracket boss thickness from *Vol 1, Pt 3, Ch 3, 4.5 Shaft brackets 4.5.7* or *Vol 1, Pt 3, Ch 3, 4.5 Shaft brackets 4.5.8* as appropriate.

4.10.7 The diameter of the propeller bracket mounting bolts is to be not less than:

$$d_b = \sqrt{\frac{Z_{xx}}{8,75\,\pi\, n h \times 10^{-5}}} \text{ mm}$$

subject to $d_{bmin} \geq t_b$ mm

where

Z_{xx} = the section modulus of the bracket arm determined from *Vol 1, Pt 3, Ch 3, 4.6 Single arm shaft brackets (‘P’ – brackets) 4.6.1* or *Vol 1, Pt 3, Ch 3, 4.7 Double arm shaft brackets (‘A’ – brackets) 4.7.2*, cm^3, as appropriate

n = the number of bolts in each row

h = the distance between rows of bolts, mm

d_b = the bolt diameter in the same material as the propeller bracket, mm

t_b = the propeller bracket boss thickness, mm.

4.10.8 Where the shaft bracket and the shaft bracket mounting bolts are of dissimilar materials (which are galvanically compatible), the diameter of the propeller bracket mounting bolts, as determined from *Vol 1, Pt 3, Ch 3, 4.10 Attachment of shaft brackets by bolting 4.10.7*, is to be modified in proportion to the square root of the yield strengths of the particular materials. The corrected bolt diameter of the dissimilar material is to be not less than the propeller bracket boss thickness.

4.10.9 The propeller bracket palms are to have fitted bolts, and suitable arrangements provided to lock the nuts.

4.10.10 A washer plate is to be provided, generally of equal dimensions to the bracket palm with thickness t_b/6 mm, subject to a minimum of 3 mm.

4.11 Alignment of shaft brackets

4.11.1 Particular care is to be paid to the alignment of shaft brackets to minimise vibration and cyclic loadings being transmitted from the propulsion shafting and propellers into the hull structure.

4.11.2 Alignment of bolted shaft brackets may be by means of suitable metallic shims or chocking resin of an approved type, *see Vol 1, Pt 3, Ch 3, 4.10 Attachment of shaft brackets by bolting 4.10.2* and *Vol 1, Pt 3, Ch 3, 4.10 Attachment of shaft brackets by bolting 4.10.3*.

4.11.3 The alignment of shaft brackets connected by welding or bonding may be facilitated by boring of the bracket boss after attachment of the shaft bracket and stern tube.

4.12 Sterntubes

4.12.1 The sterntube scantlings are to be individually considered.

4.12.2 The bottom shell, in way of the sterntube, is to be additionally reinforced by means of an insert plate to increase the bottom shell thickness by 50 per cent.

4.12.3 The sterntube should in general be connected to the shell by welding. Bolted arrangements will be specially considered.

4.12.4 Where sterntubes are to be retained by bolting they are to be provided with a substantial flange securely attached to the hull structure. Where bolts are used, the nuts are to be suitably locked.

4.12.5 Where stern tubes are to be welded to hull insert plates full penetration welding is required.

4.12.6 Where sterntubes are to be installed using a resin system, of an approved type, the requirements of *Vol 1, Pt 6, Ch 6 Material and Welding Requirements* are to be complied with.

4.12.7 The region where the shafting enters the ship, and the bearing in way, is to be adequately supported by floors or deep webs.

4.12.8 The shaft bearings are to be secured against rotation within the sterntube.

4.12.9 A suitable gland arrangement is to be provided at the inboard end of sterntubes.

4.13 Skegs

4.13.1 Skegs are to be efficiently integrated into the adjacent hull structure and their design is to facilitate this.

4.13.2 The scantlings of skegs are to be sufficient to withstand any docking forces imposed upon them.

4.14 Propeller hull clearances

4.14.1 Recommended minimum clearances between the propeller and the sternframe, rudder or hull are given in *Table 3.4.1 Recommended minimum propeller hull clearances*. These are the minimum distances considered desirable in order to expect reasonable levels of propeller excited vibration. Attention is drawn to the importance of the local hull form characteristics, shaft power, water flow characteristics into the propeller disc and cavitation when considering the recommended clearances.

Table 3.4.1 Recommended minimum propeller hull clearances

Number of blades	Hull clearances for twin screw, in metres, *see Figure 3.4.4 Propeller clearance*	
	e	*f*
3	1,20*K dp*	1,20*K dp*
4	1,00*K dp*	1,20*K dp*
5	0,85*K dp*	0,85*K dp*
6	0,75*K dp*	0,75*K dp*
Minimum value	3 and 4 blades, 0,20*dp* 5 and 6 blades, 0,16*dp*	0,15*d*

Symbols

L_R and C_B are as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*

$$K = \left(0,1 + \frac{L_R}{3050}\right)\left(\frac{3,48 C_B P_s}{L_R^2} + 0,3\right)$$

t_R = thickness of rudder, in metres measured at 0,7Rp above the shaft centreline

P_s = designed power on one shaft, in kW

R_p = propeller radius, in metres

dp = propeller diameter, in metres

Note The above recommended minimum clearances also apply to semi-spade type rudders.

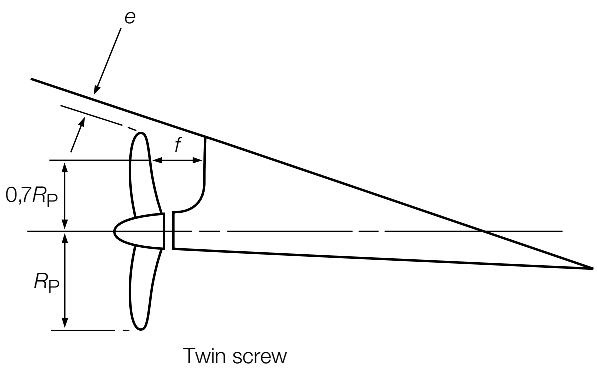


Figure 3.4.4 Propeller clearance

■ Section 5
Fixed and steering nozzles, bow and stern thrust units, ducted propellers

5.1 General

5.1.1 The requirements for scantlings for fixed and steering nozzles are given, for guidance only, in *Vol 1, Pt 3, Ch 3, 5.2 Nozzle structure* to *Vol 1, Pt 3, Ch 3, 5.4 Ancillary items* and *Table 3.5.1 Nozzle construction requirements*

5.1.2 The requirements, in general, apply to nozzles with a numeral not greater than 200, *see Vol 1, Pt 3, Ch 3, 5.1 General 5.1.2*. Nozzles exceeding this value will be specially considered.

5.2 Nozzle structure

5.2.1 For basic scantlings of the structure, *see Table 3.5.1 Nozzle construction requirements*, in association with *Figure 3.5.1 Fixed and steering nozzles*.

5.2.2 The shroud plating in way of the propeller tips is to be carried well forward and aft of this position, due allowance being made on steering nozzles for the rotation of the nozzle in relation to the propeller.

5.2.3 Fore and aft webs are to be fitted between the inner and outer skins of the nozzle. Both sides of the headbox and pintle support structure are to be connected to fore and aft webs of increased thickness. For thicknesses, *see Table 3.5.1 Nozzle construction requirements*

5.2.4 The transverse strength of the nozzle is to be maintained by the fitting of ring webs. Two ring webs are to be fitted in nozzles not exceeding 2,5 m diameter. Nozzles between 2,5 and 3,0 m in diameter are generally to have two full ring webs and a half-depth web supporting the flare plating. The number of ring webs is to be increased as necessary on nozzles exceeding 3,0 m in diameter. Where ring webs are increased in thickness in way of the headbox and pintle support structure in accordance with *Table 3.5.1 Nozzle construction requirements*, the increased thickness is to be maintained to the adjacent fore and aft web.

5.2.5 Local stiffening is to be fitted in way of the top and bottom supports which are to be integrated with the webs and ring webs. Continuity of bending strength is to be maintained in these regions.

5.2.6 Fin plating thickness is to be not less than the cone plating, and the fin is to be adequately reinforced. Solid fins are to be not less than 25 mm thick.

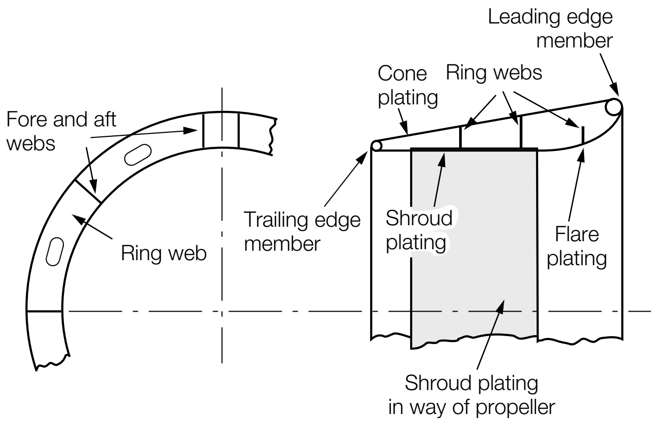


Figure 3.5.1 Fixed and steering nozzles

Table 3.5.1 Nozzle construction requirements

Item	Requirement
(1) Nozzle Numeral	$N_N = 0{,}01 P d_P$
(2) Shroud plating in way of propeller blade tips	For $N_N \leq 63$ $t_s = (11 + 0{,}1 N_N)$ mm For $N_N > 63$ $t_s = (14 + 0{,}052 N_N)$ mm
(3) Shroud plating clear of blade tips, flare and cone plating, wall thickness of leading and trailing edge members	$t_p = (t_s - 7)$ mm but not less than 8 mm
(4) Webs and ring webs	As item (3) except in way of headbox and pintle support where $t_W = (t_s + 4)$ mm
(5) Nozzle stock	Combined stresses in stock at lower bearing ≤ 92,7 N/mm^2 Torsional stress in upper stock ≤ 62,0 N/mm^2
(6) Solepiece and strut	Bending stresses not to exceed 70,0 N/mm^2
Symbols	

N_N	=	a numeral dependent on the nozzle requirements
P	=	power transmitted to the propellers, in kW
d_P	=	diameter of the propeller, in metres
t_S	=	thickness of shroud plating in way of propeller tips, in mm
t_p	=	thickness of plating, in mm
t_W	=	thickness of webs and ring webs in way of headbox and pintle support, in mm
Note Thicknesses given are for carbon steel. Reductions in thickness will be considered for certain stainless steels.		

5.2.7 Care is to be taken in the manufacture of the nozzle to ensure its internal preservation and watertightness. The preservation and testing are to be as required for rudders, *see Vol 1, Pt 6 Hull Construction in Steel*.

5.3 Nozzle stock and solepiece

5.3.1 Stresses, derived using the maximum side load on the nozzle and fin acting at the assumed centre of pressure, are not to exceed the values given in *Table 3.5.1 Nozzle construction requirements*, in both the ahead and astern conditions.

5.4 Ancillary items

5.4.1 The diameter of pintles and the diameter and first moment of area about the stock axis of coupling bolts are to be derived from *Vol 1, Pt 3, Ch 3, 2.23 Pintles* and *Vol 1, Pt 3, Ch 3, 2.24 Bolted couplings* respectively.

5.4.2 Suitable arrangements are to be provided to prevent the steering nozzle from lifting.

5.5 Steering gear and allied systems

5.5.1 For the requirements of steering gear, *see Vol 2, Pt 6, Ch 1 Steering Gear*.

5.6 Thruster unit wall thickness

5.6.1 The wall thickness of the unit is, in general, to be in accordance with the manufacturer's practice, but is to be not less than the thickness of the adjacent shell plating plus 10 per cent or 2 mm whichever is the greater, subject to a minimum of 7 mm.

5.7 Thruster unit installation details

5.7.1 The tunnel tube is to be fitted either between a pair of deep floors or bulkheads extending to above the design waterline or in a separate watertight compartment.

5.7.2 The shell plating thickness is to be locally increased by 50 per cent in way of tunnel thruster connections.

5.7.3 For welded tube connections the welding is to be by full penetration welding.

5.7.4 The tunnel tube is to be framed to the same standard as the surrounding shell plating.

5.7.5 The unit is to be adequately supported and stiffened.

5.8 Propeller ducting

5.8.1 Where propellers are fitted within ducts/tunnels, the plating thickness in way of the blades is to be increased by 50 per cent.

5.8.2 The tunnel wall in way of the propeller blades is to be additionally stiffened.

5.9 Surface drive mountings

5.9.1 Transoms through which surface drive systems pass and which are required to carry thrust, significant weight, torque, moment, etc. are to be adequately reinforced.

5.9.2 The thickness of transom plating in way is to be increased by 50 per cent or as advised by the drive manufacturer, whichever is the greater.

5.9.3 Steering rams are to be mounted on suitably reinforced areas of plating supported by additional internal stiffening, details of which are to be submitted for consideration.

5.10 Novel features

5.10.1 Where the Rules do not specifically define the requirements for novel features, then the scantlings and arrangements are to be determined by direct calculations. Such calculations are to be carried out on the basis of the Rules, recognised Standards and good practice, and are to be submitted for consideration.

■ *Section 6* **Waterjet propulsion systems**

6.1 Construction

6.1.1 The requirements for the construction and installation of water jet units apply irrespective of rated power.

6.1.2 Water jet ducts may be fabricated as an integral part of the hull structure, or as a bolted-in unit. In either case, detailed plans indicating dimensions, scantlings and materials of construction of the following are to be submitted in triplicate.

(a) Arrangement of the system including intended method of attachment to the hull and building-in, geometry of tunnel, shell opening, method of stiffening, reinforcement, etc.
(b) Shaft sealing arrangements.
(c) Details of any shafting support or guide vanes used in the water jet system.
(d) Details and arrangements of inspection ports, their closing appliances and sealing arrangement, etc.
(e) Details and arrangements of protection gratings and their attachments.

6.1.3 When submitting the plans requested in 6.1.2, details of the designers' loadings and their positions of application in the hull are to be submitted. These are to include maximum applied thrust, moments and tunnel pressures for which approval is sought.

6.1.4 All materials used in construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2015*.

6.1.5 Steels are to be of suitable grades in accordance with the requirements of *Vol 1, Pt 6, Ch 6 Material and Welding Requirements*.

6.1.6 Irrespective of the material used, the strength and supporting structure of all tunnels are to be examined by direct calculation procedures which are to be submitted. In no case are the scantlings to be taken as less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnels is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

6.1.7 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of the guard are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and susceptibility to clog with weed and other flow restricting matter.

6.1.8 The inlet profile of the tunnel is to be so designed as to provide a smooth uptake of water over the range of craft operating trims and avoid significant separation of the flow into the rotating machinery.

6.1.9 Single or multiple water jet unit installations having a total rated power in excess of 500 kW are to be contained within their own watertight compartment. Other arrangements for maintaining watertight integrity may be specially considered depending on the size and installation layout.

6.1.10 For details of machinery requirements, *see Vol 2, Pt 4, Ch 2 Water Jet Systems*.

6.2 Water jet propulsion systems – Installation

6.2.1 Standard units built for 'off the shelf' supply and which include the duct are to be installed strictly in accordance with the manufacturer's instructions, *see also Vol 1, Pt 3, Ch 3, 6.1 Construction 6.1.4*.

6.2.2 Integral water jet ducts are to be constructed in accordance with the manufacturer's requirements and the relevant plans submitted as required by *Vol 1, Pt 3, Ch 3, 6.1 Construction*.

6.2.3 Where load is transmitted into the transom and/or bottom shell, the thickness of the plating adjacent to the jet unit is to be increased. The increase in thickness is to be not less than 50 per cent of the calculated transom and bottom plating thicknesses respectively or 8 mm, whichever is the greater. Such reinforcement is to extend beyond the surrounding stiffening structure.

6.2.4 For 'bolted-in' units, hull receiving rings are to be of a material compatible with the hull. Scantlings of the receiving rings are to be as required by the jet unit manufacturer and suitably edge prepared prior to welding in place. The receiving ring is to be installed using an approved welding procedure. Where a manufacturer's specification is not provided, full details are to be submitted.

6.2.5 Bolt sizes and spacings are to be specified by the manufacturer, and are to be of suitable marine grade, insulated as appropriate and locked by suitable means.

6.2.6 Where studs are proposed for the receiving ring(s), the remaining thickness below the depth of blind tap is to be not less than the bottom shell plating thickness plus 2 mm. Bottoms of all blind taps are to be free of sharp corners.

6.2.7 The use of approved alignment resins may be considered where accurate seating and faying surfaces are required. Details are to be submitted for consideration and approval.

6.2.8 Where a water jet unit forms an integral part of the hull structure, such units are to be installed using an approved weld procedure and in accordance with the manufacturer's instructions. Materials to be welded are to be of compatible specifications.

6.2.9 Water jet units transmitting thrust into the transom structure are to be supported by a system of radial, athwartship and vertical stiffening. Drawings are to be accompanied by a set of detailed structural calculations. Where complex installations are proposed, a finite element model may be submitted in lieu of direct calculations.

6.2.10 Water jet units transmitting thrust to a bottom shell connection or intermediate tunnel connection are to be supported by additional stiffening, the details of which are to be submitted.

■ *Section 1*
Introduction

1.1 General

1.1.1 The requirements of this Chapter are applicable to all ship types. If required, reference should be made to the specified subdivision and stability standard(s)

1.1.2 Provisions covering acceptable arrangements for the watertight and weathertight integrity of the hull and spaces within the hull are to be read in conjunction with the limits defined in *Vol 1, Pt 3, Ch 1, 1.3 Loading*.

1.1.3 Requirements are given for watertight and weathertight steel hatches and doors, securing arrangements, coamings, also closing arrangements for other miscellaneous openings, ventilators, air pipes, magazine blow out plates and discharges. For side shell doors for main opening and bow doors, *see Vol 1, Pt 4, Ch 3 Special Features*.

1.1.4 Requirements are also given for other outfitting arrangements including protection of personnel, lagging of structure and the fixing of equipment lifting eyes.

1.1.5 A boundary or a closing appliance is considered weathertight if it is capable of preventing the passage of water into the ship in any sea condition. Weathertightness can be obtained, by design, where closing arrangements are constructed of steel (or equivalent) and are capable of being closed by clamping devices or bolts. The joining parts are to be gasketed and for all practical purposes have an equivalent structural integrity and tightness to the surrounding structure.

1.1.6 The requirements for closing appliances in this Chapter are suitable for weathertight arrangements. When closing appliances are designed to comply with the requirements for CBRN Defence, they will be considered as being equivalent to the weathertight requirements of this Chapter.

■ *Section 2*
Hatches and miscellaneous openings on the weather deck

2.1 Hatch covers

2.1.1 The hatch covers on the weather decks of all ships are to be steel plated, stiffened by webs or stiffeners, hinged and secured by clamping devices. Weathertightness to be achieved by means of gaskets. The means of securing are to be such that

weathertightness can be maintained in any sea condition. Where toggles are fitted, their diameter and spacing are to be in accordance with ISO standards or equivalent.

2.1.2 The scantlings of covers are not to be less than the rule thickness for the deck at that point. Where other materials are used, equivalent scantlings are to be provided. The scantlings apply basically to rectangular covers, with the stiffening members arranged primarily in one direction and carrying a uniformly distributed load. The covers are assumed to be simply supported. Where covers are stiffened by a grillage formation, and also where point loads are applied to any type of cover, the scantlings are to be determined from direct calculations.

2.1.3 In the case of flush hatch covers or of covers on coamings of lesser height than required by *Vol 1, Pt 3, Ch 4, 2.3 Manholes and flush escape hatches 2.3.1*, their scantlings, the securing and sealing arrangements and the drainage of gutterways will be specially considered.

2.1.4 Where hatchways are trunked through one or more lower decks, and hatchway beams and covers are dispensed with at the intermediate decks, the hatchway beams, coamings and covers immediately below the trunk are to be adequately strengthened. Plans are to be submitted for approval.

2.1.5 Small hatches, including escape hatches, are to be situated clear of RADHAZ areas and RAS stores receiving areas and storing routes. Small hatches and their securing devices are to be easily operable by one person in the expected operating conditions; this is typically achieved if the maximum operating force does not exceed 150N. Where necessary, counterbalance weights, springs or other equivalent mechanisms are to be provided to assist the user in opening and closing the hatch. Any mechanism fitted is to be designed so as not to present a hazard to persons using the hatch. Failure of the mechanism is not to prevent the operation of the hatch.

2.1.6 Where practicable access hatches to below spaces are to be arranged to allow for the passage of personnel wearing breathing apparatus as well as the transfer of injured personnel. For this purpose the opening is to be a minimum of 600mm x 600mm. Hand holds and foot holds are to be located both within the space being accessed and externally in the vicinity of hatch so as to enable ease of access.

2.1.7 Where portable plates are required in decks for unshipping machinery, or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced deck or the surrounding structure is suitably compensated. Portable plates are to be secured by gaskets and closely spaced bolts at a pitch not exceeding five diameters or equivalent naval standard.

2.2 Hatch coamings

2.2.1 The height of coamings above the upper surface of the weather deck, measured above sheathing if fitted, is to be not less than 300 mm. For exposed decks immediately above the design draft, e.g. quarter decks and well decks, coaming heights are to be no less than 600 mm. Coaming of a height no less than 450 mm may be provided if the hatch cover is kept closed and a small access hatch is provided in the hatch cover.

2.2.2 The height of coamings of hatchways closed by steel covers fitted with gaskets and clamping devices are to be as specified in *Vol 1, Pt 3, Ch 4, 2.2 Hatch coamings 2.2.1*, but may be reduced, or the coamings may be omitted entirely, if the safety of the ship is not thereby impaired in any sea condition. Special attention will be given in such cases to the scantlings of the covers, to their gasketing and securing arrangements and to the drainage of recesses in the deck.

2.2.3 The height of coamings may be required to be increased on ships where this is shown to be necessary by the stability and watertight subdivision calculations required by *Vol 1, Pt 3, Ch 2, 1.3 Watertight and weathertight integrity*.

2.2.4 Vertical coamings are to have a thickness, t, in mm not less than the greater of the following:

(a) $t = 0,008 H_c \sqrt{k} + 1,0$ mm

(b) Rule thickness of the deck in the position fitted

where

H_c = the coaming height

k = local strength steel factor, *see Vol 1, Pt 6, Ch 5 Structural Design Factors*

2.2.5 Vertical coamings are to be stiffened at their upper edge by a substantial rolled or fabricated section. Additional support is to be arranged as necessary.

2.3 Manholes and flush escape hatches

2.3.1 Manholes are to be closed by substantial covers capable of being made watertight. The covers are to be permanently attached.

2.3.2 Flush escape hatches are to be closed by substantial weathertight covers capable of being opened and closed from either side unless specified otherwise for hatches that provide access to high security areas such as magazines or to prevent access from open decks. The covers are to be permanently attached.

2.4 Hatchways within enclosed superstructures or lower decks

2.4.1 The requirements of this Section are to be complied with where it is necessary to maintain the weathertight envelope.

2.4.2 Access hatches within a superstructure or deckhouse need not be provided with means for closing if all openings in the surrounding bulkheads have weathertight closing appliances.

2.4.3 Consideration should be given to positioning weathertight or gastight hatches on lower decks in accordance with a specified standard for CBRN purposes.

2.5 Openings on the tops and sides of enclosed structures on the weather deck

2.5.1 Openings on the tops and sides of enclosed structures on the weather deck up to a height of 2,5 m are to be weathertight. In the forward 0,25L_R the height should be taken to 5 m. The height of openings may be required to be increased where this is shown necessary by the stability and watertight subdivision calculation required by *Vol 1, Pt 1, Ch 2, 1.1 Framework of Classification*. The weather deck as defined in *Vol 1, Pt 3, Ch 1, 5.4 Decks 5.4.2* may be stepped or recessed for the purpose of this Chapter. Special consideration will be given to the position of the weather deck of NS1 ship types.

2.6 Magazine blow out plates

2.6.1 Where blow out plates are required they are to be secured by sealing arrangements adequate to meet the weathertightness and operational requirements. They are to be of an equivalent strength to the deck in which they are fitted.

2.6.2 Blow out plates are to be permanently attached.

■ *Section 3*
Doors and accesses on weather decks

3.1 General

3.1.1 Access openings in:

(a) superstructure bulkheads;
(b) deckhouses protecting openings leading into enclosed superstructures or to spaces below the weather deck; and
(c) deckhouse on a deckhouse protecting an opening leading to a space below the weather deck,

are to be fitted with doors of steel or other equivalent material, permanently and strongly attached to the bulkhead and framed, stiffened and fitted so that the whole structure is of equivalent strength to the unpierced bulkhead, and weathertight when closed. The doors are to be gasketed and secured weathertight by means of clamping devices or equivalent arrangements, permanently attached to the bulkhead or to the door. Doors are generally to open outwards and are to be capable of being operated and secured from both sides. The sill heights are to be as required by *Vol 1, Pt 3, Ch 4, 3.1 General 3.1.3* and *Vol 1, Pt 3, Ch 4, 3.1 General 3.1.4*.

3.1.2 Fixed lights in doors are to comply with the requirements for side scuttles lights as given in *Vol 1, Pt 3, Ch 4, 6.1 Application* Hinged steel deadlights may be external.

3.1.3 The height of doorway sills above the weather deck sheathing, if fitted, is to be not less than 300 mm.

3.1.4 For exposed decks immediately above the design draught, e.g. quarter decks and well decks, sill heights are to be no less than 450 mm.

3.1.5 When the closing appliances of openings in superstructures and deckhouses do not comply with *Vol 1, Pt 3, Ch 4, 3.1 General 3.1.1*, interior deck openings are to be treated as if exposed on the weather deck.

3.1.6 The height of door sills may be required to be increased on ships where this is shown to be necessary by the stability and watertight subdivision calculations required by *Vol 1, Pt 3, Ch 2, 1.2 Definitions*.

3.1.7 Where portable plates are required for unshipping machinery, or for other similar reasons, they may be accepted provided they are of equivalent strength to the unpierced bulkhead and are secured by gaskets and close spaced bolts at a pitch not exceeding five diameters or equivalent naval standard.

3.1.8 The sill heights of accesses closed by covers which are secured by closely spaced bolts or otherwise kept permanently closed at sea will be specially considered.

3.1.9 Special consideration will be given to access on the weatherdeck where for operational purposes it is not possible to provide a sill meeting *Vol 1, Pt 3, Ch 4, 3.1 General 3.1.3*or *Vol 1, Pt 3, Ch 4, 3.1 General 3.1.4*

3.2 Magazine blow out plates

3.2.1 Where blow out plates are required, they are to be secured by sealing arrangements adequate to meet the weathertightness and operational requirements. They are to be of an equivalent strength to the deck in which they are fitted.

3.2.2 Blow out plates are to be permanently attached.

■ *Section 4*
Watertight doors and hatches in watertight subdivision boundaries

4.1 General

4.1.1 Watertight doors and hatches are to be designed in accordance with a recognised Standard. They are to be manufactured under LR Survey and surveyed during installation. They are to be tested in accordance with the LR survey procedures, operated under working conditions and tested in place, *see Vol 1, Pt 6, Ch 6 Material and Welding Requirements*.

4.1.2 Doors and hatches are to be of equivalent strength to the unpierced subdivision. They are to be approved for the maximum head of water indicated by the approved damage stability calculations.

4.1.3 Where watertight doors of the sliding type are permitted by the subdivision and stability standard, they are to be capable of being operated by efficient hand-operated gear, both at the door itself and from an accessible position above the vertical limit of watertight integrity. Means are to be provided at the remote operating position to indicate whether the door is open or closed. The time necessary for the complete closure of the door, when operating by hand gear, is not to exceed 90 seconds with the ship in the upright position.

4.1.4 Power operated doors are to be capable of being opened and closed locally by both power and efficient hand operated mechanisms in accordance with *Vol 1, Pt 3, Ch 4, 4.1 General 4.1.3*.

4.1.5 Indicators are to be provided on the bridge, ship command centre or operations room showing whether power operated watertight doors and hatches are open or closed, *see Vol 2, Pt 9, Ch 9, 5.9 Watertight doors*.

4.1.6 Where manually operated hinged watertight doors are fitted, a suitable procedural system is to be implemented to ensure that such doors remain closed when at sea unless specific authorisation is sought.

4.1.7 Watertight doors and hatches are to be capable of being operated from both sides of the watertight division except for access to high security areas such as magazines or to prevent access from open decks.

4.1.8 Sliding watertight doors are to be capable of being operated up to the heel and trim angles specified in the subdivision and stability standard, but not less than 15° heel either way. Consideration is also to be given to the forces which may act on either side of the door as may be experienced when water is flowing through the opening, applying a static head equivalent to a water height of at least 1 m above the sill on the centreline of the door.

4.1.9 Where practicable watertight access hatches in vertical watertight subdivisions are to be arranged to allow for the passage of personnel wearing breathing apparatus as well as the transfer of injured personnel. For this purpose the opening is to be a minimum of 800mm x 600mm. Hand holds and foot holds are to be located on both sides of the subdivision in the vicinity of the hatch so as to enable ease of access.

Section 5
Side scuttles and windows

5.1 General

5.1.1 Side lights, portlights and portholes are considered to be side scuttles.

5.1.2 Side scuttles are defined as being round or oval openings with an area not exceeding 0,16 m^2.

5.1.3 Windows are defined as being rectangular openings generally, and round or oval openings with an area exceeding 0,16 m^2.

5.1.4 A plan showing the location of side scuttles and windows is to be submitted.

5.1.5 Side scuttles and windows together with their glasses and deadlights if fitted, are to be of an approved design or in accordance with a specified standard(s).

5.1.6 Side scuttles to spaces within enclosed superstructures, or deckhouses on or above the weather deck are to be fitted with efficient, hinged, inside deadlights and capable of being effectively closed and secured watertight.

5.1.7 All side scuttles are to be of the non-opening type.

5.1.8 Windows are not to be fitted below the lowest weather deck or in end bulkheads of superstructures.

5.1.9 If fitted in a deckhouse or superstructures in the forward 0,25L_R, windows are to be provided with strong, hinged, steel, weathertight storm covers. However, if there is an opening leading below deck, this opening is to be treated as being on an exposed deck and is to be protected as required by *Vol 1, Pt 3, Ch 4, 2.2 Hatch coamings 2.2.1*

5.1.10 Side scuttles and windows set inboard from the shell on the weather deck, protecting direct access below, are either to be provided with strong permanently attached deadlights or, where they are accessible, strong permanently attached external steel storm covers instead of internal deadlights.

5.1.11 Side scuttles and windows set inboard from the shell on the weather deck, not protecting direct access below, do not require deadlights or storm covers.

5.1.12 Cabin bulkheads and doors are considered to provide effective protection between side scuttles or windows and access below.

5.1.13 Where windows are permitted in an exposed bulkhead on the weather deck in the forward 0,25L_R , strong external storm covers which may be portable and stored adjacent are to be provided.

5.1.14 Where the bridge is on, or not more than 5,0 m above, the weather deck in lieu of storm covers being provided for the bridge windows, a weathertight cover, fitted to a coaming of not less than 230 mm in height around the internal stairway opening within the bridge, may be accepted. If this arrangement is accepted, adequate means of draining the bridge are to be provided.

5.1.15 If necessary, for practical considerations, the storm covers may be in two parts.

5.1.16 Laminated toughened safety glass may also be used for windows but the total thickness will need to be greater than that required for the equivalent sized window using monolithic toughened safety glass. The equivalent thickness of laminated toughened safety glass is to be determined from the following formula:

$$T_{L1}{}^2 + T_{L2}{}^2 + ...T_{Ln}{}^2 = T_S{}^2$$

where

n = number of laminates

T_L = thickness of glass laminate

T_S = Rule thickness of toughened safety glass.

Alternative arrangements that do not meet the above thickness requirement will be specially considered, provided that equivalent strength and bending stiffness to that of a single, thermally toughened pane of thickness T_s can be demonstrated in a four-point bending test in accordance with EN-ISO 1288-3 or an equivalent recognised National or International Standard, using no fewer

than ten samples. The lower limit of the 90 per cent confidence level interval for the laminated pane shall not be less than the same for monolithic toughened safety glass. Small scale punch test or ring-in-ring test methods shall not be used.

5.1.17 Rubber frames are not acceptable for windows.

■ *Section 6* Ventilators

6.1 Application

6.1.1 This Section applies to all ship types and provides requirements for ventilators. Reference should be made to the specified subdivision and stability standard(s).

6.1.2 For requirements regarding down flooding in connection with stability and watertight subdivision, *see Vol 1, Pt 3, Ch 2, 1.3 Watertight and weathertight integrity*.

6.2 Protection

6.2.1 In all spaces where mechanical damage is likely, all air and sounding pipes, scuppers and discharges, including their valves, controls and indicators, are to be well protected. This protection is to be of steel or other equivalent material.

6.3 General

6.3.1 Special care is to be taken in the design and positioning of ventilator openings and coamings, particularly in the region of the forward end of superstructures and other points of high stress. The deck plating in way of the coamings is to be efficiently stiffened.

6.3.2 Ventilators from tunnels passing through decks are to have scantlings suitable for withstanding the pressures to which they may be subjected and are to be made watertight.

6.4 Coamings

6.4.1 The scantlings and height of ventilator coamings exposed to the weather are to be not less than required by *Table 4.6.1 Ventilator coaming requirements* but the thickness need not exceed that of the adjacent deck or bulkhead plating. In particularly exposed positions, the height of coamings and scantlings may be required to be increased.

Table 4.6.1 Ventilator coaming requirements

Height (measured above sheathing if fitted)	(1) z_c = 900 mm for locations defined in Note 2 z_c = 760 mm elsewhere
Thickness	(2) $t_c = 5,5 + 0,01\, d_v$ mm where 7,5 mm $\le t_c \le$10,0 mm
Support	(3) If z_c > 900 mm the coaming is to be specially supported
Symbols	
t_c = thickness of coaming, in mm z_c = height of coaming, in mm d_v = internal diameter of coaming, in mm	
Note (1) Where the height of the ventilator exceeds that given in Item (1), the thickness given by (2) may be gradually reduced, above that height, to a minimum of 6,5 mm. The ventilator is to be adequately stayed. Note (2) For exposed decks immediately above the design waterline, e.g. quarter decks and well decks.	

6.4.2 The height of ventilator coamings may be required to be increased on ships where this is shown to be necessary by the stability and watertight subdivision calculations required by the specified subdivision and stability standard(s), *see Vol 1, Pt 1, Ch 2, 1.1 Framework of Classification 1.1.9*. The specified standard may require that the height of all ventilator coamings are above the angle of down flooding, *see Vol 1, Pt 3, Ch 2, 1.2 Definitions*.

6.4.3 For gooseneck ventilators, the coaming height is to be measured to the underside of the bend, this being the lowest point through which water on deck could pass freely to spaces below.

6.4.4 Where wall vents are fitted with an internal baffle which rises above the lower edge of the exterior opening, the coaming height is measured to the top of the baffle.

6.4.5 Ventilator coaming heights may be reduced on ships assigned a service area notation **SA4**. Coaming heights are to be as high as practicable, with a minimum height of 300 mm.

6.5 Closing appliances

6.5.1 All ventilator openings are to be provided with efficient weathertight closing appliances of steel or other equivalent material unless the height of the coaming is greater than 2,5 m above the weather deck or 5 m on exposed deck immediately above the design waterline, e.g. quarter decks and well decks.

6.5.2 Where ventilators are proposed to be led overboard through an enclosed lower deck space the closing arrangements are to be submitted for approval. If such ventilators are led overboard more than 4,5 m above the damage control deck, closing appliances may be omitted, provided that satisfactory baffles and drainage arrangements are provided, as in the case of air intakes or exhaust openings for machinery spaces, which may be arranged in the sides of the ship.

6.5.3 Mushroom ventilators closed by a head revolving on a centre spindle (screw-down head) are acceptable, but the diameter is not to exceed 300 mm.

6.5.4 Mushroom ventilators with a fixed head and closed by a screw-down plate (screw-down cover) may be accepted up to a diameter of 750 mm within the forward 0,25L_R.

6.5.5 Wall ventilators (jalousies) may be accepted provided they are capable of being closed weathertight by hinged steel gasketed covers secured by bolts or toggles.

6.5.6 A ventilator head not forming part of the closing arrangements is to be not less than 6,5 mm thick.

6.6 Machinery spaces

6.6.1 In general, ventilators necessary to supply the machinery space continuously are to have coamings of sufficient height to comply with *Vol 1, Pt 3, Ch 4, 6.6 Machinery spaces 6.6.1* without having to fit weathertight closing appliances. Ventilators to emergency generator rooms are to be so positioned that closing appliances are not required.

6.6.2 Where due to ship size and arrangement this is not practicable, lesser heights for machinery space ventilator coamings fitted with weathertight closing appliances may be permitted if specified in combination with other suitable arrangements to ensure uninterrupted, adequate supply of ventilation to these spaces.

■ *Section 7*
Air pipes

7.1 General

7.1.1 Air and sounding pipes are to comply with the requirements of *Vol 2, Pt 7, Ch 2, 10 Air, overflow and sounding pipes*

7.1.2 Striking plates of suitable thickness, or their equivalent, are to be fitted under all sounding pipes.

7.1.3 Air pipes are to be situated clear of areas where damage may occur, such as RAS landing areas and store routes or helicopter decks.

7.2 Height of air pipes

7.2.1 The height of air pipes from the upper surface of decks exposed to the weather, to the point where water may have access below is normally to be not less than:

- 760 mm on exposed decks immediately above the design draught, e.g. quarter decks and well decks.
- 450 mm measured above deck sheathing, where fitted elsewhere.

7.2.2 Lower heights may be approved in cases where these are essential for the working of the ship, provided that the design and arrangements are otherwise satisfactory. In such cases, efficient, permanently attached closing appliances as required by *Vol 1, Pt 3, Ch 4, 7.3 Closing appliances 7.3.1* are to be of an approved automatic type.

7.2.3 The height of air pipes may be required to be increased on ships where this is shown to be necessary by the stability and watertight subdivision calculations required by *18, Ch 1, 1 Background 1.1*. An increase in height may also be required when air pipes to fuel oil and settling tanks are situated in positions where sea water could be temporarily entrapped, e.g. in recesses in the sides and ends of superstructures or deckhouses, between hatch ends, behind high sections of bulwark, etc.. This may entail an increase in tank scantlings, *see also Vol 1, Pt 6, Ch 3 Scantling Determination*.

7.2.4 Air pipes are generally to be led to an exposed deck. *See also Vol 2, Pt 7, Ch 2, 10.4 Termination of air pipes 10.4.4*.

7.2.5 Where air pipes are led through the side of superstructures, the opening is to be at least 2,3 m above the design waterline.

7.2.6 The minimum wall thickness of air pipes in positions indicated in *Vol 1, Pt 3, Ch 4, 7.2 Height of air pipes 7.2.1* is to be:

- 6,0 mm for pipes of 80 mm external diameter or smaller.
- 8,5 mm for pipes of 165 mm external diameter or greater.

(a)

Intermediate minimum thicknesses are to be determined by linear interpolation.

7.2.7 Air pipe coaming heights may be reduced on ships assigned a service area notation **SA4**. Coaming heights are to be as high as practicable, with a minimum height of 300 mm.

7.3 Closing appliances

7.3.1 All openings of air and sounding pipes are to be provided with permanently attached, satisfactory means of closing to prevent the free entry of water (*see also Vol 1, Pt 3, Ch 4, 7.2 Height of air pipes 7.2.2* and *Vol 2, Pt 7, Ch 2, 10.6 Air pipe closing appliances 10.6.2*).

7.3.2 Closing appliances are to be of an approved automatic type.

■ *Section 8* Scuppers and sanitary discharges

8.1 General

8.1.1 Scuppers sufficient in number and size to provide effective drainage are to be fitted in all decks.

8.1.2 Scuppers draining weather decks and spaces within superstructures or deckhouses not fitted with efficient weathertight doors are to be led overboard.

8.1.3 Where the freeboard is such that the deck edge forming the vertical limit of watertight integrity is immersed when the ship heels 5° or less, scuppers and discharges which drain spaces below this deck, or spaces within intact superstructures or deckhouses on this deck fitted with efficient weathertight doors, are to be led to the bilges in the case of scuppers or to suitable sanitary tanks in the case of sanitary discharges. Where the freeboard is such that the deck edge forming the vertical limit of watertight integrity is immersed when the ship heels greater than 5° then they may be led overboard and fitted with means of preventing water from passing inboard in accordance with *Vol 1, Pt 3, Ch 4, 8.2 Closing appliances*.

8.1.4 In ships where an approved fixed pressure water spray fire-extinguishing system is fitted in vehicle, magazines or hangar spaces, deck scuppers of not less than 150 mm diameter are to be provided port and starboard, spaced about 9,0 m apart. Where the design capacity of the drencher system exceeds an application of water at a rate 5 litres per square metre of deck area by 10 per cent or more, the scupper area will require to be increased accordingly. After installation the two adjacent sections with the greatest aggregate drencher capacity are to be tested in operation to ensure that there is no build-up of water on the deck. The mouth of the scupper is to be protected by bars.

8.1.5 Where a sewage system is fitted, the shipside valves on the discharge pipe from the effluent tank(s) and the by-pass system are to comply with *Vol 1, Pt 3, Ch 4, 8.2 Closing appliances*.

8.1.6 The minimum wall thickness of pipes not indicated in *Vol 1, Pt 3, Ch 4, 8.2 Closing appliances 8.2.6* is to be:

- 4,5 mm for pipes of 155 mm external diameter or smaller.
- 6,0 mm for pipes of 230 mm external diameter or greater.

Intermediate minimum thicknesses are to be determined by linear interpolation.

8.1.7 For the use of non-metallic pipe, *see Vol 2, Pt 7, Ch 1, 11 Pipe connections*

8.1.8 Scuppers and discharge pipes should not normally pass through fuel oil tanks. Where scuppers and discharge pipes pass, unavoidably, through fuel oil tanks, and are led through the shell within the tanks, the thickness of the piping should be at least the same thickness as Rule shell plating in way, derived from the appropriate Chapters, but need not exceed 19 mm.

8.1.9 Piping within tanks is to be tested in accordance with *Naval Survey Guidance for Steel Ships*, or an otherwise specified and agreed standard.

8.1.10 All piping is to be adequately supported.

8.2 Closing appliances

8.2.1 In general, each separate overboard discharge is to be fitted with a screw-down non-return valve capable of being operated from a position always accessible and above the damage control deck. An indicator is to be fitted at the control position showing whether the valve is open or closed. A machinery space, whether manned or unattended (i.e. with **UMS** notation), is considered accessible. Spaces with access only by bolted manholes are not considered accessible.

8.2.2 Where an approved fire pressure waterspray fire-extinguishing system is provided in an enclosed vehicle space, magazines or hangar spaces, the scupper controls are to be operated from a position above the damage control deck, and outside the space protected by the fire-extinguishing system, and are to be protected from mechanical damage.

8.2.3 Where the vertical distance from the design draught to the inboard end of the discharge pipe exceeds $0{,}01L_R$ the discharge may be fitted with two automatic non-return valves without positive means of closing, instead of the screw-down non-return valve, provided that the inboard valve is always accessible for examination under service conditions.

8.2.4 Where the vertical distance from the design waterline to the inboard end of the discharge pipe exceeds $0{,}02L_R$, a single automatic non-return valve without positive means of closing may be fitted, *see Figure 4.8.1 Diagrammatic arrangement of discharge valves*

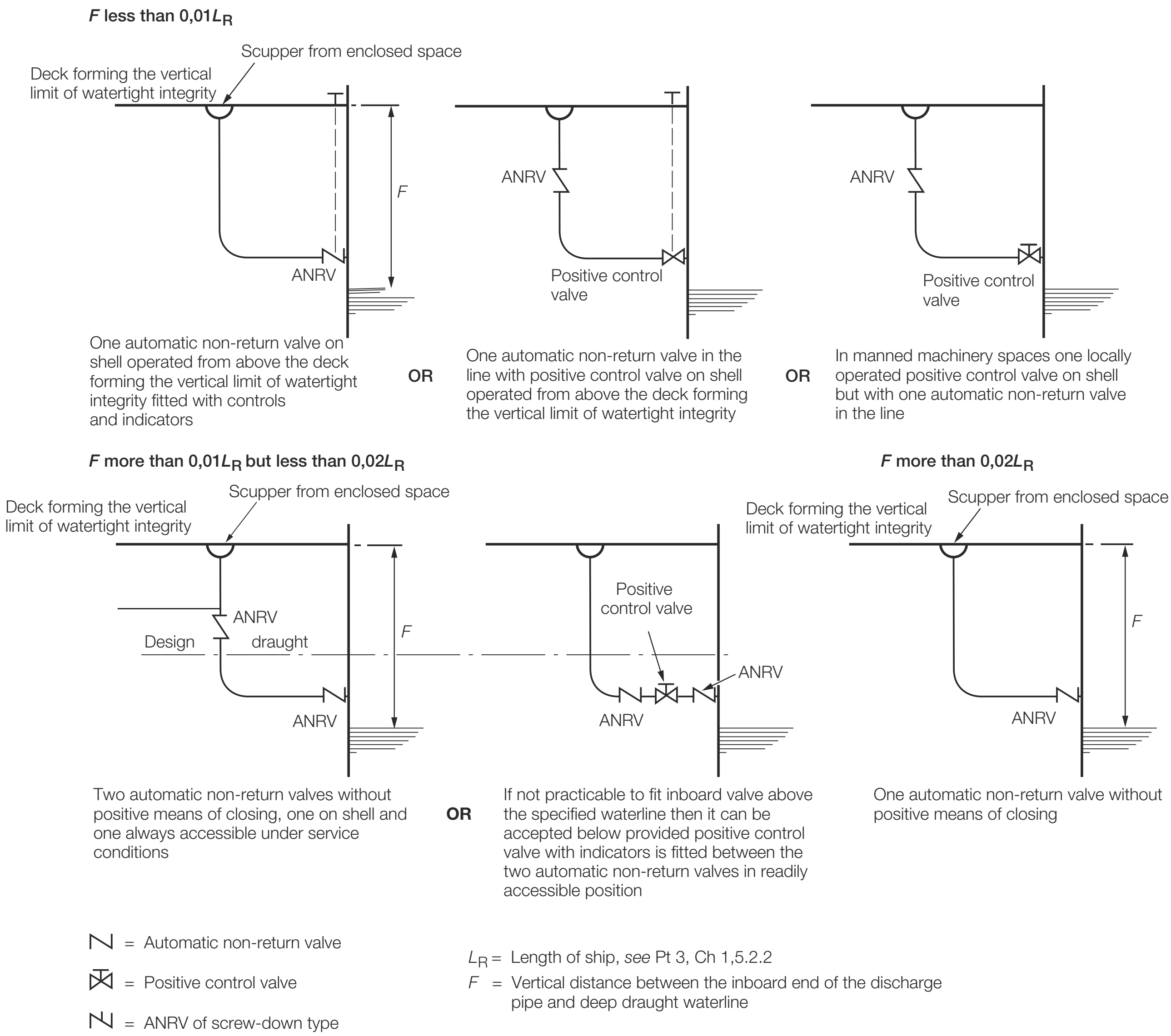


Figure 4.8.1 Diagrammatic arrangement of discharge valves

8.2.5 The requirements for non-return valves are applicable only to those discharges which remain open during the normal operation of the ship. For discharges which are closed at sea, a single screw-down valve operated from the weather deck is considered to provide sufficient protection.

8.2.6 Scuppers and discharge pipes originating at any level which penetrate the shell either more than 450 mm below the deck forming the vertical limit of watertight integrity or less than 600 mm above the deep draught waterline, are to be fitted with an automatic non-return valve at the shell. This valve, unless required by *Vol 1, Pt 3, Ch 4, 8.1 General 8.1.3*, may be omitted provided the piping has a minimum wall thickness of:

- 7,0 mm for pipes of 80 mm external diameter or smaller.
- 10,0 mm for pipes of 180 mm external diameter.
- 12,5 mm for pipes of 220 mm external diameter or greater.

Intermediate minimum thicknesses are to be determined by linear interpolation. Unless required by *Vol 1, Pt 3, Ch 4, 8.1 General 8.1.8*, the maximum thickness need not exceed 12,5 mm.

8.2.7 The outboard valve is to be mounted directly on the shell and secured in accordance with *Vol 2, Pt 7, Ch 1 Piping Design Requirements*. If this is impracticable, a short distance piece of rigid construction may be introduced between the valve and the shell.

8.2.8 If a valve is required by *Vol 1, Pt 3, Ch 4, 8.1 General 8.1.3*, this valve should preferably be fitted as close as possible to the point of entry of the pipe into the tank. If fitted below the weather deck, the valve is to be capable of being controlled from an easily accessible position above the weather deck. Local control is also to be arranged, unless the valve is inaccessible. An indicator is to be fitted at the control position showing whether the valve is open or closed.

8.2.9 Valves for maintaining watertight integrity such as ship side valves and fittings (other than those on scuppers and sanitary discharges), are to comply with the requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements* and *Vol 2, Pt 7, Ch 2 Ship Piping System*.

8.3 Rubbish chutes and similar discharges

8.3.1 Rubbish chutes and similar discharges should be constructed of mild steel piping or plating of shell thickness. Other materials will be specially considered. Openings are to be kept clear of the sheerstrake and areas of high stress concentration.

8.3.2 Rubbish chute hoppers are to be provided with a hinged weathertight cover at the inboard end with an interlock so that the discharge flap and hopper cover cannot be open at the same time. The hopper cover is to be secured closed when not in use, and a suitable notice displayed at the control position.

8.3.3 Where the inboard end of the hopper is less than 0,01L_R above the design draught, a suitable valve with positive means for closing is to be provided in addition to the cover and flap in an easily accessible position above the design draught. The valve is to be controlled from a position adjacent to the hopper and provided with an open/shut indicator. The valve is to be kept closed when not in use, and a suitable notice displayed at the valve operating position.

8.4 Materials for valves, fittings and pipes

8.4.1 All shell fittings and valves required by *Vol 1, Pt 3, Ch 4, 8.2 Closing appliances* are to be of steel, bronze or other approved ductile material; ordinary cast iron or similar material is not acceptable. Materials are to satisfy the requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2015*.

8.4.2 All these items, if made of steel or other approved material with low corrosion resistance, are to be suitably protected against wastage.

8.4.3 The lengths of pipe attached to the shell fittings, elbow pieces or valves are to be of galvanised steel or other equivalent approved material.

■ *Section 9*
Bulwarks, guard rails, raised walkways and other means for the protection of crew and embarked personnel

9.1 General requirements

9.1.1 Bulwarks or guard rails are to be provided at the boundaries of exposed decks. Bulwarks or guard rails are to be not less than 1,0 m in height measured above sheathing, and are to be constructed as required by this Section. Consideration will be given to cases where this height would interfere with the normal operation of the ship. Guard rails provided around aircraft operating areas may be of the type which drop outwards with nets which are to comply with *Vol 1, Pt 3, Ch 4, 9.6 Safety nets*. Droppable guard rails must be capable of being secured in both the upright and lowered position. Where bulwarks or guard rails are undesirable, e.g. for radar signature purposes, alternative equivalent arrangements will be required. Guidance on radar signatures is provided in *Vol 1, Pt 4, Ch 1, 4.1 Radar signature*.

9.1.2 The freeing arrangements in bulwarks are to be in accordance with *Vol 1, Pt 3, Ch 4, 9.3 Freeing arrangements* .

9.1.3 Guard rails fitted on superstructure and exposed decks are to have at least three courses. The opening below the lowest course of guard-rails is not to exceed 230 mm. The other courses are to be spaced not more than 380 mm apart. In the case of ships with rounded gunwales, the guard-rail supports are to be placed on the flat of the deck. In other locations, guard rails with at least two courses are to be fitted.

9.1.4 Guard rails are to be fitted with fixed, removable or hinged stanchions fitted no more than 1,5 m apart. Removable or hinged stanchions shall be capable of being locked in the upright position. When retracted, collapsed or removed, the guard rails are not to impede access/egress. Stowage is to be provided for portable stanchions and stays, sited adjacent to where they are to be used.

9.1.5 At least every third stanchion is to be supported by a stay.

9.1.6 Where necessary for the normal operation of the ship, steel wire ropes may be accepted in lieu of guard rails. Wires are to be made taut by means of turnbuckles. Chains are only permitted in short lengths in way of access openings.

9.1.7 Satisfactory means for safe passage of personnel, in the form of guard rails, life-lines, handrails, gangways, underdeck passageways or other equivalent arrangements, are to be provided for the protection of the crew and embarked personnel in getting to and from their quarters, the machinery space and all other spaces used in the operation of the ship.

9.1.8 A well illuminated and ventilated underdeck passage (with a clear opening at least 0,8 m in width and 2 m in height) is to be provided as close as practicable to the weatherdeck, connecting and providing access to the following locations:

- between superstructures;
- from the forwardmost superstructure to the forward end of the vessel;
- from the aftmost superstructure to the aft end of the vessel.

9.1.9 A means of passage over obstructions such as pipes or other fittings of a permanent nature is to be provided where practicable.

9.1.10 To assist movement in adverse weather conditions, handrails are to be fitted to bulkheads in passageways and superstructure on weatherdecks.

9.1.11 Handrails are to be fitted at a height of not less than 1 m, measured from the top of the rail to the deck. Handrails should be made of steel tubes of 42,4 mm outside diameter, with a wall thickness of at least 2,6 mm.

9.1.12 Handrails are to be secured by way of supports that are not to be spaced more than 1,5 m apart. The supports are to hold the rails not less than 50 mm from the bulkhead, measured from the inside of the rail to the bulkhead.

9.1.13 Raised walkways which form escape routes or assembly areas, or provide for the transfer of heavy equipment, stores or munitions, are to comply with the requirements of *Vol 1, Pt 3, Ch 4, 9.5 Walkways*.

9.1.14 For additional requirements for the safety of embarked persons, *see Vol 3, Pt 1, Ch 6, 2.4 Safety of embarked persons*.

9.2 Bulwark construction

9.2.1 Plate bulwarks are to be stiffened by a strong rail section and supported by stays from the deck. The spacing of these stays forward of $0.93L_R$ is to be not more than 1,2 m. Elsewhere, bulwark stays are to be not more then 1,83 m apart. Where bulwarks are cut to form a gangway or other opening, stays of increased strength are to be fitted at the ends of the openings. Bulwarks are to be adequately strengthened in way of eyeplates for RAS points, and in way of mooring pipes the plating is to be doubled or increased in thickness and adequately stiffened.

9.2.2 Bulwarks should not be cut for gangway or other openings near the breaks of superstructures, and are also to be arranged to ensure their freedom from main structural stresses. *See* shell plating in appropriate Chapters.

9.2.3 The section modulus, Z, at the bottom of the bulwark stay is to be not less than:

$$Z = (33{,}0 + 0{,}44L)\, h^2 s \text{ cm}^3$$

where

h = height of bulwark from the top of the deck plating to the top of the rail, in metres

s = spacing of the stays, in metres, in accordance with *Vol 1, Pt 3, Ch 4, 10.2 Removal for access 10.2.1*

L_R = length of ship, in metres (as defined in *Vol 1, Pt 3, Ch 1, 5.1 General*), but to be not greater than 100 m.

9.2.4 In the calculation of the section modulus, only the material connected to the deck is to be included. The bulb or flange of the stay may be taken into account where connected to the deck, and where, at the ends of the ship, the bulwark plating is connected to the sheerstrake, a width of plating not exceeding 600 mm may also be included. The free edge of the stay is to be stiffened.

9.2.5 Bulwark stays are to be supported by, or to be in line with, suitable underdeck stiffening, which is to be connected by double continuous fillet welds in way of the bulwark stay connection.

9.3 Freeing arrangements

9.3.1 The following requirements are applicable to all ship types.

9.3.2 Where bulwarks on the weather decks or superstructure decks form wells, ample provision is to be made for rapidly freeing the decks of large quantities of water by means of freeing ports, and also for draining them.

9.3.3 The minimum freeing area on each side of the ship, for each well on the weather deck is to be derived from the following formulae:

(a) where the length, l, of the bulwark in the well is 20 m or less: area required = $0{,}7 + 0{,}035l$ m^2

(b) where the length, l, exceeds 20 m, area required = $0{,}07l$ m^2

l need not be taken greater than $0{,}7L_R$, where L_R is the length of the ship as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*.

9.3.4 If the average height of the bulwark exceeds 1,2 m or is less than 0,9 m, the freeing area is to be increased or decreased, respectively, by 0,004 m^2 per metre of length of well for each 0,1 m increase or decrease in height respectively.

9.3.5 The minimum freeing area for each well on a superstructure is to be half the area calculated from *Vol 1, Pt 3, Ch 4, 9.3 Freeing arrangements 9.3.3*.

9.3.6 Two-thirds of the freeing port area required is to be provided in the half of the well nearest to the lowest point of the sheer curve.

9.3.7 When the deck has little or no sheer, the freeing area is to be spread along the length of the well.

9.3.8 In ships with no sheer the freeing area as calculated from *Vol 1, Pt 3, Ch 4, 9.3 Freeing arrangements 9.3.3* is to be increased by 50 per cent. Where the sheer is less than the standard, as given in *Table 4.9.1 Standard sheer profile*, the percentage is to be obtained by linear interpolation.

Table 4.9.1 Standard sheer profile

Position from A.P.	Ordinate (in mm)
A.P.	$25\left(\frac{L_R}{3}+10\right)$
$0{,}16L_R$	$11{,}1\left(\frac{L_R}{3}+10\right)$
$0{,}33L_R$	$2{,}8\left(\frac{L_R}{3}+10\right)$
$0{,}5L_R$	0
$0{,}67L_R$	$5{,}6\left(\frac{L_R}{3}+10\right)$
$0{,}83L_R$	$22{,}2\left(\frac{L_R}{3}+10\right)$

F.P.	$50\left(\frac{L_R}{3}+10\right)$
Note 1. Sheer is measured from the deck at side to a line drawn parallel to the keel through the sheer line amidships. **Note** 2. In ships with a rake of keel, the sheer is measured in relation to a reference line drawn parallel to the design waterline.	

9.3.9 Where the length of the well is less than 10 m, or where a deckhouse occupies most of the length, the freeing port area will be specially considered but in general need not exceed 10 per cent of the bulwark area.

9.3.10 Where it is not practical to provide sufficient freeing port area in the bulwark, particularly in small ships, credit can be given for bollard and fairlead openings where these extend to the deck.

9.3.11 Where a deckhouse has a breadth less than 80 per cent of the beam of the ship, or the width of the side passageways exceeds 1,5 m, the arrangement is considered as one well. Where a deckhouse has a breadth equal to or more than 80 per cent of the beam, *B*, of the ship, or the width of the side passageways does not exceed 1,5 m, or when a screen bulkhead is fitted across the full breadth of the ship, this arrangement is considered as two wells, before and abaft the deckhouse.

9.3.12 Suitable provision is also to be made for the rapid freeing of water from recesses formed by superstructures and deckhouses, etc. in which water may be shipped and trapped. Deck gear is not to be stowed in such a manner as to obstruct unduly the flow of water to freeing port.

9.3.13 The lower edges of freeing ports are to be as near to the deck as practicable, and should not be more than 100 mm above the deck.

9.3.14 Where freeing ports are more than 230 mm high, vertical bars spaced 230 mm apart may be accepted as an alternative to a horizontal rail to limit the height of the freeing port.

9.3.15 Where shutters are fitted, the pins or bearings are to be of a non-corrodible material, with ample clearance to prevent jamming. The hinges are to be within the upper third of the port. Shutters are not to be fitted with securing appliances.

9.3.16 All ships are to have open rails for at least half the length of the exposed part of the weather deck. Alternatively, if a continuous bulwark is fitted, the minimum freeing area is to be at least 33 per cent of the total area of the bulwark. The freeing area is to be placed in the lower part of the bulwark.

9.3.17 In ships having superstructures which are open at either or both ends to wells formed by bulwarks on the open deck, adequate provision for freeing the open spaces are to be provided as follows:

The freeing port area, A_w for the open well:

$$A_w = \left(0,07l + A_c\right)\left(S_c\right)\left(\frac{0,5h_s}{h_w}\right)$$

The freeing port area, A_s for the open superstructure:

$$A_s = \left(0,07l_t\right)\left(S_c\right)\left(\frac{b_o}{l_t}\left(1-\left(\frac{l_w}{l_t}\right)^2\right)\left(\frac{0,5h_s}{h_w}\right)\right)$$

where

l_w = the length of the open deck enclosed by bulwarks, in metres.

l_s = the length of the common space within the open superstructure, in metres

l_t = $l_w + l_s$ but if 20 m or less then the freeing area is to be calculated in accordance with *Vol 1, Pt 3, Ch 4, 9.3 Freeing arrangements 9.3.3*

S_c = sheer correction factor, maximum 1,5 as defined in *Vol 1, Pt 3, Ch 4, 9.3 Freeing arrangements 9.3.8*

b_o = breadth of openings in the end bulkhead of the enclosed superstructure, in metres

h_w = distance of the well deck above the freeboard deck, in metres

h_s = one standard superstructure height

h_b = actual height of the bulwark, in metres

A_c = bulwark height correction factor taken as;

= 0 for bulwarks between 0,9 and 1,2 m in height

= $0,004 l_w \left(\frac{(h_b - 1,2)}{1,0} \right) m^2$ for bulwarks of height greater than 1,2 m and

= $0,004 l_w \left(\frac{(h_b - 0,9)}{1,0} \right) m^2$ for bulwarks of height greater than 0,9 m

To adjust the freeing port area for the distance of the well deck above the weatherdeck, for decks located more than 0,5h_s above the weatherdeck, multiply by the factor 0,5 (h_s/h_w).

9.3.18 Where a ship operates for extended periods in a cold weather environment, *see Vol 1, Pt 5, Ch 2, 4.2 Definitions 4.2.3*, closing devices fitted to freeing port arrangements are to remain effective. The arrangement will be specially considered.

9.4 Free flow area

9.4.1 The effectiveness of the freeing port area in bulwarks of vessels not fitted with a continuous deck obstruction, depends on the free flow across the deck.

9.4.2 The free flow area is the net total longitudinal area of the transverse passageways or gaps between hatchways and superstructures or deckhouses, due account being made for any obstructions such as equipment or other fittings. The height of passageways or gaps used in the calculation of the area is the height of the bulwark.

9.5 Walkways

9.5.1 Walkways are to be designed to an agreed specified standard.

9.5.2 Plans are to be submitted showing the proposed scantlings and arrangements of the structure.

9.5.3 The design loads used are to be as given in *Vol 1, Pt 5, Ch 3, 5.3 Pressure on internal decks, Pin 5.3.1*. Where it is intended that the walkway be used for the transfer or storage of equipment or other substantial items, the design loads are to be agreed considering the loads given in *Vol 1, Pt 5, Ch 3, 5.3 Pressure on internal decks, Pin 5.3.1*.

9.5.4 For the design of the supporting structure of walkways, the applicable self weight of the walkway structure is to be added to the total load derived in *Vol 1, Pt 3, Ch 4, 9.5 Walkways 9.5.3*.

9.6 Safety nets

9.6.1 Safety netting used around flight decks is to be arranged so as to safely arrest the fall of personnel. For this purpose the netting is to be raised at the outboard edge by an approximate angle of 10 degrees to the horizontal. The netting is to extend a minimum of 1,25 metres in the horizontal plane. It is recommended that the outboard edge is not above the level of the landing area but in no case is it to protrude greater than 250mm. Materials for the netting are to be specially considered, due consideration is to be given to the fire resistance and weathering properties.

9.6.2 The design load applied to safety nets and their supporting structure is to be taken as 2,7kN per metre of netting acting at the centre of the net in addition to the self-weight of the structure. The sag of the net is to be considered when resolving this force at the inner and outer fixings of the net, *see Figure 4.9.1 Safety netting sag*. Where the netting terminates at a support, the full load is to be applied to the support. The stress criteria to be applied for supports and supporting structure are given in *Table 4.9.2 Permissible stress*.

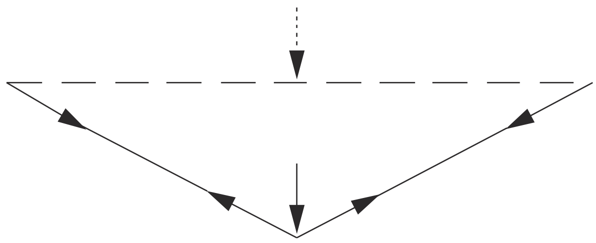


Figure 4.9.1 Safety netting sag

Table 4.9.2 Permissible stress

	Permissible stress
Bending and direct stress	$0,8\sigma_o$
Shear stress	$0,5\sigma_o$
Combined stress	$0,9\sigma_o$
Symbols	
σ_o = specified yield stress of the material, in N/mm^2	

9.7 Ladders

9.7.1 Fixed ladders of any type are to be designed in accordance with an appropriate recognised Standard, e.g. BSMA 39-1 *Vertical steel ladders*, BSMA 39-2 *Sloping steel ladders*.

9.7.2 Ladders may be constructed from alternative materials than those specified in the standards for the purposes of satisfying radar signature requirements. Equivalent levels of usability and robustness are to be demonstrated.

9.7.3 When the climbing height of a single ladder is 3m or more, fall arrest features are to be provided. Where practicable, staging platforms are to be provided for climbing heights in excess of 6m so as to divide the climbing height into multiple stages.

9.8 Means of embarkation and disembarkation

9.8.1 Accommodation ladders and embarkation ladders are to be in accordance with an appropriate recognised Standard, e.g. ISO 5488 *Accommodation ladders* or ISO 5489 *Embarkation ladders*.

■ *Section 10*
Lagging and lining of structure

10.1 General

10.1.1 Suspended floors are to be fitted and secured in such a manner as to provide access to the structure and fittings below

10.2 Removal for access

10.2.1 It is recommended that the cabin fittings and linings against the side of the ship be so fitted as to be capable of being removed when necessary. The method of attachment is not to impair the strength of the structural members.

10.2.2 Removable linings are to be fitted in areas prone to high structural degradation and areas that are critical to the structural integrity of the hull, to permit examination of these areas.

10.2.3 Decorative linings are to be manufactured of materials resistant to secondary fragmentation and combustion.

Section 11
Lifting eyes

11.1 Application

11.1.1 The following Section covers the design appraisal, testing during construction and through-life inspection of lifting eyes, with a permissible loading of 2,5 tonnes or less, installed for the purposes of shipping and unshipping equipment and machinery, and where they do not form part of a lifting appliance. Where the requirements of this Section are complied with the optional notation **LE** may be assigned.

11.1.2 The Owner is to ensure that the eyes are located in appropriate locations to enable the shipping and unshipping of equipment and machinery.

11.2 Information to be submitted

11.2.1 The following documentation is to be submitted for approval:

- Documentation detailing the range of standard lifting points to be used, *see Vol 1, Pt 3, Ch 4, 11.4 Lifting points*.

11.2.2 The following information is also to be submitted:

- A register of all equipment and machinery which is required to be shipped or unshipped during service.
- Plans detailing the shipping and unshipping routes by compartment.
- A register of all lifting points specifying the detail type, tally information and test loads.

11.3 Materials

11.3.1 Materials are to be in accordance with an agreed specified standard.

11.4 Lifting points

11.4.1 Lifting eyes are to be manufactured in accordance with an agreed specified standard.

11.4.2 A range of standard lifting point detail designs are to be selected. The range of detail types is to be appropriate for the weight of equipment and machinery which is required to be shipped or unshipped and the method of transfer which is to be used. When considering the weight of equipment and machinery the weight of the lifting gear is to be included.

11.4.3 Each standard lifting point detail is to have the following information defined:

- Permissible loading – Vertical lift.
- Permissible loading – Along eye-plate 45 degrees lift (where applicable).
- Permissible loading – Across eye-plate 45 degrees lift (where applicable).
- Material of construction.
- Method of attachment to the ship's structure.
- Method of use.
- Manufacturer's test loads.

11.4.4 The safe working load (SWL) for each of the standard detail designs is to be validated by calculation. The design load to be applied is as follows:

- 2 × SWL for the vertical lift case.
- 1,5 × SWL for the 45 degree lift case.

The permissible stresses in *Table 4.11.1 Permissible stresses* are not to be exceeded.

Table 4.11.1 Permissible stresses

	Permissible stress
Bending and direct stress	$0,8\sigma_o$
Shear stress	$0,5\sigma_o$

Combined stress	$0{,}9\sigma_o$
Symbols	
σ_o = specified yield stress of the material, in N/mm^2	

11.4.5 The weld stresses are also to be validated by calculation and confirmed as acceptable. For this purpose a factor of 0,7 is to be used.

11.5 Supporting structure

11.5.1 Lifting points are to be located at the intersection of structural members wherever possible.

11.5.2 The strength of the supporting structure is to be validated by calculation.

11.5.3 Where double tallying is used, *see Vol 1, Pt 3, Ch 4, 11.6 Tallying 11.6.2*, the unused direction is to be checked at an angle of 45 degrees for a load 0,25 times the SWL.

11.6 Tallying

11.6.1 Each lifting point is to have a tally displayed which clearly defines the permissible methods of use and the permissible loading associated with each method.

11.6.2 In general, a lifting point will have a single tally all round capability or single tally vertical lift only. A double tally is only to be used where the supporting structure would be required to be strengthened to provide all round capability but where the planned method of use does not require allround capability.

11.7 Testing

11.7.1 Each lifting eye is to be supplied with a Manufacturer's Test Certificate. A vertical lift and 45 degree lift test are to be carried out. The test load is to be 2 × SWL for the vertical lift arrangement and 1,5 × SWL for the 45 degree lift arrangement.

11.7.2 Once installed on board the ship, each lifting eye is to be load tested to 2 × SWL in the vertical direction. Documentation detailing the test loads and testing arrangement used is to be submitted to LR.

11.7.3 The weld attachment to the ship's structure of each lifting eye is to be visually inspected by a Surveyor. Where requested, Magnetic Particle Inspection is also to be carried out and the results are to be submitted to LR.

11.8 Inspection during service

11.8.1 A maintenance and inspection regime is to be developed in accordance with a recognised Standard (e.g. Merchant Shipping and Fishing Vessels (Lifting Operations and Lifting Equipment) Regulations 2006), documented and confirmed as being implemented by the attending Surveyor.

As a minimum the procedure is to:

- Define the Standard or applicable legalisation which is used to define a Responsible Person;
- Nominate an appropriate Responsible Person or persons;
- Detail any training which the Responsible Person is to receive;
- Detail any qualifications which the Responsible Person is to hold;
- State that lifting points are to be inspected by a Responsible Person prior to and after use;
- Mandate that a record is kept of when each lifting point was last inspected and by whom;
- Authorise the Responsible Person to request that the lifting eye is to be load tested in accordance with *Vol 1, Pt 3, Ch 4, 11.7 Testing 11.7.2* upon inspection;
- Authorise the Responsible Person to remove the item from service should they consider it appropriate to do so.

■ Section 1 General

1.1 Application

1.1.1 The anchoring equipment specified in this Section is suitable for ships designed for unrestricted service.

1.2 Definitions

1.2.1 The definitions for use throughout this Chapter are as indicated in the appropriate Section.

1.3 Character of classification

1.3.1 For classification purposes the character figure **1**, or the character letter **E**, is to be assigned.

1.3.2 To entitle a ship to the character **1** in its classification symbol, equipment in accordance with the requirements of Sections *Vol 1, Pt 3, Ch 5, 4 Anchors*, *Vol 1, Pt 3, Ch 5, 5 Anchor cable*, *Vol 1, Pt 3, Ch 5, 6 Mooring ropes*, *Vol 1, Pt 3, Ch 5, 8 Windlass and capstan design and testing* and *Vol 1, Pt 3, Ch 5, 9 Structural details* is to be provided. The regulations governing the assignment of the character figure **1** for equipment are given in *Vol 1, Pt 1, Ch 2 Classification Regulations*.

1.3.3 Where Lloyd's Register (hereinafter referred to as 'LR') has agreed that anchoring and mooring equipment, as defined in *Vol 1, Pt 3, Ch 5, 1.3 Character of classification 1.3.2*, need not be fitted in view of the particular service of the ship, the character letter **E** will be assigned. *See also Vol 1, Pt 1, Ch 2 Classification Regulations*

1.3.4 For ships intended to be operated only in suitable areas or conditions, other than those included in this Section, which have been agreed by LR, (as defined in *Vol 1, Pt 1, Ch 2, 3.6 Service area notations*) equipment differing from these requirements may be approved if considered suitable for the particular service on which the ship is to be engaged.

■ Section 2 Equipment Number

2.1 Equipment Number calculation

2.1.1 The anchoring and mooring equipment specified in this Section is based on an ‘Equipment Number’ which is to be calculated as follows:

$$EquipmentNumber = \Delta^{2/3} + 2,5A_t + A/10$$

where

A = area, in m^2, in profile view, of the hull, superstructures, houses, masts, etc. above the design draught which are within the Rule length of the vessel and also have a breadth greater than B/4. *See also Vol 1, Pt 3, Ch 5, 2.1 Equipment Number calculation 2.1.2*.

A_t = transverse projected area, in m^2, of the hull and of all superstructures, houses, masts, etc. above the design draught

Δ = displacement, in tonnes, of the ship at its deep draft waterline.

2.1.2 Screens and bulwarks more than 1,5 m in height are to be regarded as parts of houses when determining *A*. Where a screen or bulwark is of varying height, the portion to be included is to be that length the height of which exceeds 1,5 m.

2.1.3 For ships which have a complex above water transverse profile due to the presence of large plated masts, mast trees, large radar equipment, etc. the equipment number may need to be specially considered.

2.2 Novel ship design

2.2.1 Where a ship is of unusual form and proportions the requirement for equipment will be individually considered on the basis of the Rules.

■ *Section 3* Service area factors

3.1 General

3.1.1 For details of the service areas referred to in this Section, *see Vol 1, Pt 5, Ch 2, 2.2 Service areas*.

3.2 Service Areas SA1, SA2, SA3, SA4, SAR

3.2.1 For ships designed to operate in any service area, the equipment is to be in accordance with the requirements of *Table 5.4.1 Equipment - HHP Bower anchors and chain cables* and *Table 5.6.1 Equipment - Kedge anchors and wires, towlines and mooring lines*

■ *Section 4* Anchors

4.1 General

4.1.1 The Rules are based on the use of high holding power (HHP) type anchors.

4.1.2 When ordinary holding power anchors are used as bower anchors, the mass given in *Table 5.4.1 Equipment - HHP Bower anchors and chain cables* is to be increased by 33 per cent.

4.1.3 Where it is proposed to fit other types of anchor, the mass will be specially considered.

4.1.4 Ships are to be provided with the number of anchors as specified in *Table 5.4.1 Equipment - HHP Bower anchors and chain cables* on board which must be ready for immediate use. Where this is impractical, *see Vol 1, Pt 3, Ch 5, 9.3 Hawse pipes and anchor recesses 9.3.4*, special consideration may be given to only having one anchor ready for immediate use.

4.1.5 Where there is a high degree of redundancy in propulsion and steering and where the engine can be brought to readiness quickly, consideration may be given to the fitting of a single anchor where *Table 5.4.1 Equipment - HHP Bower anchors and chain cables* requires the fitting of two anchors.

4.1.6 Anchors are to be of an approved design. The design of all anchor heads is to be such as to minimise stress concentrations, and in particular, the radii on all parts of cast anchor heads are to be as large as possible, especially where there is considerable change of section.

4.1.7 Anchors which must be specially laid the right way up, or which require the fluke angle or profile to be adjusted for varying types of sea bed, will not generally be approved for normal ship use, but may be accepted for offshore units, floating cranes, etc. In such cases suitable tests may be required.

4.1.8 Where kedge anchors are specified, they are to be in accordance with *Table 5.6.1 Equipment - Kedge anchors and wires, towlines and mooring lines*.

4.2 Manufacture and testing of anchors

4.2.1 The requirements for the manufacture, testing and certification of anchors are contained in *Ch 10 Equipment for Mooring and Anchoring* of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

4.3 Anchor stowage

4.3.1 Anchors are generally to be housed in suitable hawse pipes, or stowed in dedicated chocks on deck.

4.3.2 Hawse pipes and anchor pockets are to be in accordance with *Vol 1, Pt 3, Ch 5, 8.7 Tests and trials*. Alternatively, roller fairleads of suitable design may be fitted. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

4.4 High Holding Power (HHP) type anchors

4.4.1 Anchors of designs for which approval is sought as high holding power anchors are to be tested in accordance with *Ch 10 Equipment for Mooring and Anchoring*.

Table 5.4.1 Equipment - HHP Bower anchors and chain cables

Equipment number		Equipment Letter	Stockless bower anchors		Stud link chain cables for bower anchors			
						Diameter, in mm		
Exceeding	Not exceeding		Number	Mass of anchor, in kg	Total length, in metres	Grade U1	Grade U2	Grade U3
50	70	A	2	135	220	14	12,5	–
70	90	B	2	180	220	16	14	–
90	110	C	2	225	247,5	17,5	16	–
110	130	D	2	270	247,5	19	17,5	–
130	150	E	2	315	275	20,5	17,5	–
150	175	F	2	360	275	22	19	–
175	205	G	2	428	302,5	24	20,5	–
205	240	H	2	495	302,5	26	22	20,5
240	280	I	2	585	330	28	24	22
280	320	J	2	675	357,5	30	26	24
320	360	K	2	765	357,5	32	28	24
360	400	L	2	855	385	34	30	26
400	450	M	2	968	385	36	32	28
450	500	N	2	1080	412,5	38	34	30
500	550	O	2	1193	412,5	40	34	30
550	600	P	2	1305	440	42	36	32

600	660	Q	2	1440	440	44	38	34
660	720	R	2	1575	440	46	40	36
720	780	S	2	1710	467,5	48	42	36
780	840	T	2	1845	467,5	50	44	38
840	910	U	2	1980	467,5	52	46	40
910	980	V	2	2138	495	54	48	42
980	1060	W	2	2295	495	56	50	44
1060	1140	X	2	2475	495	58	50	46
1140	1220	Y	2	2655	522,5	60	52	46
1220	1300	Z	2	2835	522,5	62	54	48
1300	1390	A †	2	3038	522,5	64	56	50
1390	1480	B †	2	3240	550	66	58	50
1480	1570	C †	2	3443	550	68	60	52
1570	1670	D †	2	3668	550	70	62	54
1670	1790	E †	2	3938	577,5	73	64	56
1790	1930	F †	2	4208	577,5	76	66	58
1930	2080	G †	2	4500	577,5	78	68	60
2080	2230	H †	2	4838	605	81	70	62
2230	2380	I †	2	5175	605	84	73	64
2380	2530	J †	2	5518	605	87	76	66
2530	2700	K †	2	5850	632,5	90	78	68
2700	2870	L †	2	6225	632,5	92	81	70
2870	3040	M †	2	6525	632,5	95	84	73
3040	3210	N †	2	6975	660	97	84	76
3210	3400	O †	2	7425	660	100	87	78
3400	3600	P †	2	7875	660	102	90	78
3600	3800	Q †	2	8325	687,5	105	92	81
3800	4000	R †	2	8775	687,5	107	95	84
4000	4200	S †	2	9225	687,5	111	97	87
4200	4400	T †	2	9675	715	114	100	87
4400	4600	U †	2	10125	715	117	102	90
4600	4800	V †	2	10575	715	120	105	92
4800	5000	W †	2	11025	742.5	122	107	95
5000	5200	X †	2	11550	742.5	124	111	97
5200	5500	Y †	2	12075	742.5	127	111	97
5500	5800	Z †	2	12675	742.5	130	114	100
5800	6100	A*	2	13350	742.5	132	117	102
6100	6500	B*	2	14100	742.5	—	120	107

6500	6900	C*	2	15000	770	—	124	111
6900	7400	D*	2	16125	770	—	127	114
7400	7900	E*	2	17250	770	—	132	117
7900	8400	F*	2	18375	770	—	137	122
8400	8900	G*	2	19500	770	—	142	127
8900	9400	H*	2	20625	770	—	147	132
9400	10000	I*	2	21750	770	—	152	132
10000	10700	J*	2	23250	770	—	157	137
10700	11500	K*	2	24750	770	—	157	142
11500	12400	L*	2	26625	770	—	162	147
12400	13400	M*	2	28875	770	—	—	152
13400	14600	N*	2	31500	770	—	—	157
14600	16000	O*	2	34500	770	—	—	162

4.5 Super High Holding Power (SHHP) type anchors

4.5.1 Proposals to use anchors of the SHHP type will be subject to special consideration.

4.5.2 Final acceptance will be dependent upon satisfactory strength and performance tests.

4.5.3 Anchors of designs for which approval is sought as super high holding power anchors are to be tested at sea to show that they have holding powers of at least four times those of approved standard stockless anchors of the same mass.

4.6 Tolerances

4.6.1 The mass of each bower anchor given in *Table 5.4.1 Equipment - HHP Bower anchors and chain cables* is for anchors of equal mass. The masses of individual anchors may vary by ±7 per cent of the masses given in the Table, provided that the total mass of the anchors is not less than would have been required for anchors of equal mass.

4.6.2 The mass of the head, including pins and fittings, of an ordinary stockless anchor is to be not less than 60 per cent of the total mass of the anchor.

4.6.3 When stocked bower or kedge anchors are to be used, the mass 'ex stock' is to be not less than 80 per cent of the mass given in *Table 5.4.1 Equipment - HHP Bower anchors and chain cables* for ordinary stockless bower anchors and *Table 5.6.1 Equipment - Kedge anchors and wires, towlines and mooring lines* for kedge anchors. The mass of the stock is to be 25 per cent of the total mass of the anchor, including the shackle, etc. but excluding the stock.

4.7 Identification

4.7.1 Identification of anchors which have been tested is to be in accordance with *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials.

■ *Section 5* Anchor cable

5.1 General

5.1.1 Anchor cable may be of stud link chain, short link chain, wire rope or fibre rope, subject to the requirements of this Section.

5.2 Chain cable

5.2.1 The length and diameter of chain cable is to be as indicated in *Table 5.4.1 Equipment - HHP Bower anchors and chain cables*

5.2.2 Short link chain cable may be accepted provided that the breaking load is not less than that of stud link chain cable of the diameter required by *Table 5.4.1 Equipment - HHP Bower anchors and chain cables*

5.2.3 Chain cables are to be steel in accordance with the requirements of *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials.

5.2.4 Grade U1 material having a tensile strength of less than 400 N/mm^2 is not to be used in association with high holding power anchors. Grade U3 material is to be used only for chain 20,5 mm or more in diameter.

5.2.5 In addition to *Vol 1, Pt 3, Ch 5, 5.2 Chain cable 5.2.3* special consideration will be given to the use of chain cable of alloy steel. Alloy steel is to be of a suitable type, details of which are to be submitted for consideration.

5.2.6 The form and proportion of links and shackles are to be in accordance with *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials.

5.2.7 Where kedge anchors are used in association with chain cable, this cable may be either stud link or short link.

5.2.8 Test certificates issued in accordance with *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials are to be signed by the Surveyors when the cables are placed on board the ship.

5.2.9 Arrangements are to be provided for the safe use of cable when mooring to a buoy, securing alongside hazardous or exposed jetties or preparing to be towed. Alternative arrangements to meet these requirements without the use of cable are to be submitted for consideration.

5.3 Wire rope

5.3.1 Steel wire ropes are to be manufactured, tested and certified as required by *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials.

5.4 Cable clench

5.4.1 Provision is to be made for securing the inboard ends of the cables to the structure. This attachment should have a working strength of not less than 63,7 kN or 10 per cent of the breaking strength of the chain cable, whichever is the greater, and the structure to which it is attached is to be adequate for this load. Attention is drawn to the advantages of arranging that the cable may be slipped from an accessible position outside the chain cable locker. The proposed arrangement for slipping the chain cable, if constructed outside the chain locker, must be made watertight.

5.5 Cable stopping and release arrangements

5.5.1 It is recommended that suitable bow chain stoppers be provided. The scantlings of these chain stoppers are outside the scope of the Rules, however the structure in way is to be designed with due regard to the applied loading. Support under chain stopping arrangements is to be to the satisfaction of the Surveyor.

5.6 Cable locker

5.6.1 Adequate storage is to be provided to accommodate the full length of anchor cable.

5.6.2 The chain locker is to be of a capacity and depth adequate to provide an easy direct lead for the cable into the chain pipes, when the cable is fully stowed. Chain or spurling pipes are to be of suitable size and provided with chafing lips. The port and starboard cables are to be separated by a division in the locker.

5.6.3 Chain lockers fitted abaft the collision bulkhead are to be weathertight and the space to be efficiently drained.

■ Section 6 Mooring ropes

6.1 Mooring ropes

6.1.1 Ships under 90 m require mooring lines as specified in *Table 5.6.1 Equipment - Kedge anchors and wires, towlines and mooring lines*

6.1.2 The lengths of individual mooring lines in *Table 5.6.1 Equipment - Kedge anchors and wires, towlines and mooring lines* may be reduced by up to seven per cent of the Table length, provided that the total length of mooring lines is not less than would have resulted had all lines been of equal length. Proposals to fit individual mooring lines of reduced length to suit the particular service will be specially considered.

6.1.3 Ships 90 m and over in length do not require mooring lines as a classification item. It is recommended, however, that the sum of the strengths of all the mooring lines supplied to such ships should be not less than the Rule breaking load of one anchor cable as required by *Table 5.4.1 Equipment - HHP Bower anchors and chain cables*, based on Grade U2 chain. On ships regularly using exposed berths, twice the above total strength of mooring ropes is desirable.

6.1.4 It is recommended that not less than four mooring lines be carried on ships exceeding 90 m in length, and not less than six mooring lines on ships exceeding 180 m in length. The length of mooring lines should be not less than 200 m, or the length of the ship, whichever is the lesser.

6.1.5 For ease of handling, fibre ropes should be not less than 20 mm diameter. All ropes having breaking strengths in excess of 736,0 kN and used in normal mooring operations are to be handled by, and stored on, suitably designed winches. Alternative methods of storing should give due consideration to the difficulties experienced in manually handling ropes having breaking strengths in excess of 490,0 kN

6.2 Materials

6.2.1 Mooring lines may be of steel wire rope, natural fibre or synthetic fibre. The diameter, construction and specification of wire or natural fibre mooring lines are to comply with the requirements of *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials. Where it is proposed to use synthetic fibre ropes, the size and construction will be specially considered.

6.2.2 The design loads applied to deck fittings by *Vol 1, Pt 3, Ch 5, 6.6 Support structure of deck fittings* relate to conventional fibre ropes (i.e. polypropylene, polyester and nylon). If other materials are used i.e. HMPE, consideration should be given to the elongation properties and therefore the design load applied to deck fittings.

6.2.3 Wire rope mooring lines used in association with winches (on which the rope is stored on the winch drum) are to be of suitable construction.

6.3 Testing and certification

6.3.1 Mooring ropes are to be tested and certified in accordance with *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials.

6.4 Bollards, fairleads and bull rings

6.4.1 Means are to be provided to enable mooring lines to be adequately secured on board ship.

6.4.2 It is recommended that the total number of suitably placed bollards on either side of the ship and/or the total brake holding power of mooring winches should be capable of holding not less than 1,5 times the sum of the maximum breaking strengths of the mooring lines required or recommended.

6.4.3 Bollards, fairleads and bull rings are to be located on longitudinals, beams and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the mooring load. Other equivalent arrangements (Panama chocks etc.) will be considered providing the strength is confirmed as adequate for the intended use.

6.4.4 It is recommended that shipboard fittings are selected in accordance with an Industry standard (e.g. ISO3913 Shipbuilding Welded Steel Bollards) accepted by the Society. When the shipboard fitting is not selected from an accepted Industry standard, the design load used to assess its strength and its attachment to the ship is to be in accordance with *Vol 1, Pt 3, Ch 5, 6.6 Support structure of deck fittings 6.6.3* and the design is to be submitted for approval.

6.4.5 The SWL of each shipboard fitting is not to exceed 80 per cent of the design load as per *Vol 1, Pt 3, Ch 5, 6.6 Support structure of deck fittings 6.6.3*. It is to be marked (by weld bead or equivalent) on the deck fittings used for mooring. The SWL with its intended use is to be noted in the mooring arrangement plan or other information available on board for the guidance of the Master. These requirements for SWL apply for a single post basis (no more than one turn of one cable). The arrangement plan is to explicitly prohibit the use of mooring lines outside of their intended function.

6.5 Mooring winches

6.5.1 Mooring winches where provided are to be suitable for the intended purpose.

6.5.2 Mooring winches are to be fitted with drum brakes, the strength of which is sufficient to prevent unreeling of the mooring line when the rope tension is equal to 80 per cent of the breaking strength of the rope as fitted on the first layer on the winch drum.

Table 5.6.1 Equipment - Kedge anchors and wires, towlines and mooring lines

Equipment number		Not exceeding	Equipment Letter	Kedge anchor wire or chain (1) & (2)		Mooring lines (2)		
Exceeding	Mass of stockless kedge anchor, in kg			Minimum length, in metres	Minimum breaking strength, in kN	Number	Minimum length of each line, in metres	Minimum breaking strength, in kN
50	70	A	68	110	46	3	80	34
70	90	B	90	110	58	3	100	37
90	110	C	113	124	75	3	110	39
110	130	D	135	124	90	3	110	44
130	150	E	158	138	90	3	120	49
150	175	F	180	138	122	3	120	54
175	205	G	214	151	106	3	120	59
205	240	H	248	151	140	4	120	64
240	280	I	292	165	166	4	120	69
280	320	J	338	179	195	4	140	74
320	360	K	383	179	225	4	140	78
360	400	L	428	193	257	4	140	88
400	450	M	484	193	292	4	140	98
450	500	N	540	206	328	4	140	108
500	550	O	597	206	328	4	140	123
550	600	P	653	220	366	4	160	132
600	660	Q	720	220	406	4	160	147
660	720	R	788	220	448	4	160	157
720	780	S	855	233	491	4	160	172
780	840	T	923	233	540	4	170	186
840	910	U	990	233	585	4	170	201
910	980	V	1069	248	635	4	170	216
980	1060	W	1148	248	685	4	170	230
1060	1140	X	1238	248	685	4	180	250

1140	1220	Y	1328	261	740	4	180	270
1220	1300	Z	1418	261	795	4	180	284
1300	1390	A †	1519	261	855	4	180	309
1390	1480	B †	1620	275	905	4	180	324
1480	1570	C †	1721	275	970	5	190	324
1570	1670	D †	1834	275	1030	5	190	333
1670	1790	E†	1969	289	1095	5	190	353
1790	1930	F†	2104	289	1155	5	190	378
1930	2080	G†	2250	289	1225	5	190	402
2080	2230	H†	2419	302	1290	5	200	422
2230	2380	I†	2588	302	1395	5	200	451
2380	2530	J†	2759	302	1505	5	200	480
2530	2700	K†	2925	316	1580	6	200	480
2700	2870	L†	3113	316	1690	6	200	490
2870	3040	M†	3263	316	1805	6	200	500
3040	3210	N†	3488	330	1805	6	200	520
3210	3400	O†	3713	330	1925	6	200	554
3400	3600	P†	3938	330	2045	6	200	588
3600	3800	Q†	4163	344	2130	6	200	618
3800	4000	R†	4388	344	2255	6	200	647
4000	4200	S†	4613	344	2340	7	200	647

Note 1. The rope used for kedge anchor wire is to be constructed of not less than 72 wires, made up into six strands.

Note 2. Steel wire and fibre ropes used for mooring lines and kedge anchors are to meet the requirements of *Ch 10, 6 Steel wire ropes* and *Ch 10, 7 Fibre ropes* the Rules for Materials respectively.

Note 3. Wire ropes for mooring lines used in association with mooring winches (on which the rope is stored on the winch drum) are to be of suitable construction.

Note 4. Irrespective of strength requirements, no fibre rope is to be less than 20 mm diameter.

6.6 Support structure of deck fittings

6.6.1 Plans are to be of sufficient detail for plan approval purposes. Plans covering the following items are to be submitted for approval:

- Strong points, bollards and fairleads, *see Vol 1, Pt 3, Ch 5, 6.6 Support structure of deck fittings 6.6.4*.
- Support structure and foundations of towing equipment.

6.6.2 A mooring arrangements plan is to be submitted for information and is to include the following in respect of each shipboard fitting:

- Location on the ship.
- Fitting type.
- Safe working load (SWL).
- Purpose of fitting (mooring/harbour towing/escort towing).
- Manner of applying towing or mooring line load, including limiting fleet angles.

A mooring arrangement plan is to be provided on board the ship for the guidance of the Master.

6.6.3 The design load to be applied to the supporting structure of mooring fittings is to be 1,25 times the minimum breaking strength of the mooring line according to *Table 5.6.1 Equipment - Kedge anchors and wires, towlines and mooring lines* for the ship's corresponding equipment number.

6.6.4 The design load to be applied to the supporting structure of winches is to be 1,25 times the rated maximum holding power of the winch or the rated maximum pull power, whichever is greater.

6.6.5 The design load is to be applied according to the arrangement shown on the mooring arrangement plan. The point of action of the force on the fitting is to be taken as the point of attachment of the mooring line or towline or at a change in its direction. The total design load applied to a fitting need not be more than twice the design load, *see Figure 5.7.1 Design load applied to fittings*.

6.6.6 The reinforced members (carling) beneath shipboard fittings are to be effectively arranged for any variation of direction (horizontally and vertically) of the mooring forces (which is to be not less than the design load) acting through the arrangement of connection to the shipboard fittings. Other arrangements will be specially considered, provided that the strength is confirmed as adequate for the service.

6.6.7 The stresses in shipboard fittings associated with mooring are not to exceed the specified minimum yield stress of the material in bending and 60 per cent of the specified minimum yield stress of the material in shear considering the design load.

■ *Section 7*
Towing arrangements

7.1 Definition

7.1.1 Towing can be defined as either receiving motive assistance from, or rendering it to, another vessel.

7.2 Application

7.2.1 The towing arrangements specified in this section are applicable to NS1, NS2 and NS3 category ships carrying the corresponding optional towing arrangement notation.

7.2.2 The strength of strong points, fittings and machinery are to be proof tested unless type approved.

7.2.3 In general, ships complying with the requirements of this section will be eligible to be classed with the notation **TA1, TA2** or **TA3.**

7.2.4 **TA1** This notation will be assigned when an appraisal has been made of the towing arrangements and strength performance of the supporting structures in accordance with the Rules. This notation recognises the most severe weather conditions, *see Table 5.7.2 Design weather factors* and *Table 5.7.3 Environmental conditions*.

7.2.5 **TA2** This notation will be assigned when an appraisal has been made of the towing arrangements and strength performance of the supporting structures in accordance with the Rules. This notation recognises weather conditions less severe than TA1, *see Table 5.7.2 Design weather factors* and *Table 5.7.3 Environmental conditions*.

7.2.6 **TA3** This notation will be assigned when an appraisal has been made of the towing arrangements and strength performance of the supporting structures in accordance with the Rules. This notation recognises the least severe weather conditions, *see Table 5.7.2 Design weather factors* and *Table 5.7.3 Environmental conditions*.

7.2.7 These three levels of towing arrangements in 7.2.4 to 7.2.6 recognise towing a ship of similar displacement at 6 knots in defined environmental conditions (*see Table 5.7.3 Environmental conditions*) and are appropriate for the weather conditions found in the equivalent service areas, i.e. **TA1** corresponds to the weather conditions found with service area notation **SA1**.

7.2.8 Where alternative requirements to the breaking load of the towing hawser required by *Vol 1, Pt 3, Ch 5, 7.6 Strength requirements for towing arrangements 7.6.1* are specified, and have been complied with, the ship will be entitled to the notation **TA(NS)**. These alternative requirements are to be clearly defined and referenced in the Certificate of Class. The load specified in the alternative is to replace the BL value given by the expression in *Vol 1, Pt 3, Ch 5, 7.6 Strength requirements for towing arrangements 7.6.1*.

7.2.9 Where the towline complies with the strength requirements of *Table 5.7.1 Equipment - Minimum length and breaking strength of towlines* as applicable to merchant ships for the related equipment number, the ship will be entitled to the assignment

of the **TA(S)** notation. The breaking load specified in *Table 5.7.1 Equipment - Minimum length and breaking strength of towlines* is to replace the BL value given by the expression in *Vol 1, Pt 3, Ch 5, 7.6 Strength requirements for towing arrangements 7.6.1*.

7.2.10 Towing operations are to be in accordance with the towing, mooring and arrangements plan or equivalent information which is required to be placed on board. *See Vol 1, Pt 3, Ch 5, 7.4 Information required*.

Table 5.7.1 Equipment - Minimum length and breaking strength of towlines

Equipment number		Not Exceeding	Towline	
Exceeding	Equipment Letter		Minimum length, in metres	Minimum strength, in kN
50	70	A	180	98
70	90	B	180	98
90	110	C	180	98
110	130	D	180	98
130	150	E	180	98
150	175	F	180	98
175	205	G	180	112
205	240	H	180	129
240	280	I	180	150
280	320	J	180	174
320	360	K	180	207
360	400	L	180	224
400	450	M	180	250
450	500	N	180	277
500	550	O	190	306
550	600	P	190	338
600	660	Q	190	370
660	720	R	190	406
720	780	S	190	441
780	840	T	190	518
840	910	U	190	518
910	980	V	190	559
980	1060	W	200	603
1060	1140	X	200	647
1140	1220	Y	200	691
1220	1300	Z	200	738
1300	1390	A†	200	786
1390	1480	B†	200	836
1480	1570	C†	220	888
1570	1670	D†	220	941
1670	1790	E†	220	1024
1790	1930	F†	220	1109
1930	2080	G†	220	1168
2080	1130	H†	240	1259
1130	1380	I†	240	1356

1380	2530	J†	240	1453
2530	2700	K†	260	1471
2700	2870	L†	260	1471
2870	3040	M†	260	1471
3040	3210	N†	280	1471
3210	3400	O†	280	1471
3400	3600	P†	280	1471
3600	3800	Q†	300	1471
3800	4000	R†	300	1471
4000	4000	S†	300	1471
4000	4400	T†	300	1471
4400	4600	U†	300	1471
4600	5000	V†	300	1471
5000	5200	W†	300	1471
5200	5500	X†	300	1471
5500	5500	Y†	300	1471
5500	5800	Z†	300	1471
5800	6100	A*	300	1471

Table 5.7.2 Design weather factors

Applicable notation	Wind speed coefficient, C_{mw}	Weather factor, K
TA1	0,0150	8
TA2	0,0129	7,2
TA3	0,0108	6,3

Table 5.7.3 Environmental conditions

Beaufort Scale	Equivalent Mean Wind Speed (knots)	Wind Speed Coefficient, C_{mw}	Weather Factor, K
1–4	1–16	0,0025	3
5	17–21	0,0046	3,8
6	22–27	0,0067	4,7
7	28–33	0,0086	5,5
8	34–40	0,0108	6,3
9	41–47	0,0129	7,2
10+	48+	0,0150	8

7.3 Materials

7.3.1 Towing hawsers and towing pennants can be of steel wire rope, natural fibre or synthetic fibre. The diameter, construction and specification of steel wire or fibre towlines are to comply with *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials. Where synthetic fibre ropes are used the size and construction will be specially considered.

7.3.2 Where a length of chafing chain is included in the arrangement it is to comply with *Ch 10 Equipment for Mooring and Anchoring* of the Rules for the Materials.

7.3.3 The design loads applied to deck fittings by this Section relate to conventional fibre ropes (i.e. polypropylene, polyester and nylon). Consideration should be given to the elongation properties of the actual line used.

7.3.4 Wire ropes used in association with winches (on which the rope is stored on the winch drum) are to be of suitable construction.

7.4 Information required

7.4.1 Plans are to be of sufficient detail for plan approval purposes. Plans covering the following items are to be submitted for approval:

- Strong points, bollards and fairleads, *see Vol 1, Pt 3, Ch 5, 7.5 Towing arrangements 7.5.7*.
- Support structure and foundations of towing equipment.

7.4.2 The towing arrangement plan is to be submitted for information. It is to include the following in respect of each shipboard fitting:

- Location on the ship.
- Fitting type.
- Safe working load (SWL).
- Manner of applying towing line load, including limiting fleet angles.

The towing arrangement plan is to be provided on board the ship for the guidance of the Master.

7.5 Towing arrangements

7.5.1 A towing arrangement is to be provided at both the fore and aft end of the ship.

7.5.2 The fixed towing equipment is to comprise a securing arrangement which is a strong point and may be in the form of a stopper bollard, bracket, deck clench or towing slip. A fairlead, rollers or other appropriate towline guides as necessary are to be included in the arrangement.

7.5.3 Loose towing equipment is to comprise a towing hawser and a towing pennant. The towing pennant may comprise a length of chafing chain. In the absence of a length of chafing chain suitable arrangements (e.g. a low friction sheath) are to be provided.

7.5.4 Fairleads and guides are to be designed so as to prevent excessive bending stress in the towing hawser, towing pennant or chafing chain, whichever is applicable. The bending ratio of the guides bearing surface to the diameter of the applicable towline element is not to be less than 7 to 1. For fibre rope towing hawsers and towing pennants the bending ratio is to comply with the rope manufacturer's specification.

7.5.5 The fairlead or guide is to have an opening large enough to allow the passage of the largest element of the loose towing equipment.

7.5.6 The fairlead or guide is to be fitted as close to the deck as practicable and in a position so that the tow will be approximately parallel to the deck when under tension between the strong point and the guide.

7.5.7 The selection of shipboard fittings is to be made by the shipyard in accordance with an acceptable National or International standard. If the shipboard fitting is not selected from an acceptable National or International standard then the design load used to assess its strength and its attachment to the ship is to be in accordance with the design load given in *Vol 1, Pt 3, Ch 5, 7.6 Strength requirements for towing arrangements 7.6.3*. The design is to be submitted for approval. Any weld, bolt or equivalent device connecting the shipboard fitting to the supporting structure is part of the shipboard fitting and is subject to the National or International standard applicable to that shipboard fitting.

7.5.8 Deck fittings and strong points are to be located on longitudinals, beams and/or girders, which are part of the deck construction so as to facilitate efficient distribution of the towing load. Other equivalent arrangements will be considered, providing the strength is confirmed as adequate for the intended use.

7.5.9 To avoid chafing, the arrangement is to be designed so that no element of the loose towing equipment, when under tension, is to contact with the ship's hull at any point other than those specified as a securing arrangement, fairlead or guide. The final point of contact of the towline with the ship is to be positioned as close as practicable to the centre line so as to reduce the adverse effect on manoeuvrability.

7.5.10 The chafing arrangement is to extend a minimum of 3 m outboard of the fairlead or guide when in the deployed position and 2 m inboard.

7.5.11 The loose towing equipment is to be located as near as practicable to the strong point and is to be designed to be capable of being rigged and deployed in the absence of power. It is recommended that extra loose gear meeting the requirements of this Section be carried on board to provide for redundancy.

7.5.12 The minimum length of the towing hawser is to be as given in *Table 5.7.1 Equipment - Minimum length and breaking strength of towlines*.

7.5.13 Irrespective of strength requirements, no fibre rope is to be less than 20 mm in diameter.

7.5.14 The SWL of each shipboard fitting is to be clearly marked, by weld bead or equivalent, on each of the fittings used for towing, *see Vol 1, Pt 3, Ch 5, 7.6 Strength requirements for towing arrangements 7.6.10*.

7.6 Strength requirements for towing arrangements

7.6.1 The minimum Breaking Load (hereinafter referred to as *BL*), of the towing hawser carried on board the ship is assessed, in tonnes, is not to be less than that calculated below:

$$BL = (0{,}03\Delta^{2/3} + (C_{mw} A_t))\,K$$

where

Δ = displacement, in tonnes, to the deep draught waterline

C_{mw} = wind speed coefficient, which is to be taken from *Table 5.7.2 Design weather factors* for the relevant notation

K = weather factor, which is to be taken from *Table 5.7.2 Design weather factors* for the relevant notation

A_t = transverse projected area, in m^2, of the hull and of all superstructures, houses, masts, etc. above the design draught

7.6.2 The strength of other loose towing equipment e.g. links, shackles rings and chafing chain is to be determined on the basis of a design load equal to 1,25 times the *BL* of the towing hawser.

7.6.3 The strength of shipboard fittings and their supporting structure is to be determined on the basis of a design load equal to 1,25 times the *BL* of the towing hawser. The design load is to be applied through the towline according to the arrangement shown on the towing arrangement plan. The point of action of the force on the fitting is to be taken as the point of attachment of the mooring line or towline or at a change in its direction. The total design load applied to a fitting need not be more than twice the design load, *see Figure 5.7.1 Design load applied to fittings*.

7.6.4 The stress in all loose and fixed towing equipment constructed of steel, and its supporting structure, is not to exceed the specified minimum yield stress of the material in bending and 60 per cent of the specified minimum yield stress of the material in shear. Special consideration will be given if the vessel and/or towing equipment is not constructed of steel.

7.6.5 The reinforced members (carling) beneath shipboard fittings are to be effectively arranged for any variation of direction (horizontally and vertically) of the towing forces (which is to be not less than the design load) acting through the arrangement of connection to the shipboard fittings. Other arrangements will be specially considered provided that the strength is confirmed as adequate for the service.

7.6.6 For the assessment of fairleads and their supporting structure, due consideration is to be given to lateral loads. The strength of the fairlead is to be sufficient for all angles of towing load up to 90° horizontally from the ship's centreline and 30° vertically from the horizontal plane.

7.6.7 For the assessment of a strong point and its supporting structure, the applied load is to be in the direction that the towing pennant or towing hawser will take up during normal deployment. It is also to be applied at the maximum height possible above the deck for that specific type of strong point.

7.6.8 The structural arrangements of strong points, bollards and fairleads are to be such that continuity will be ensured. Abrupt changes in section; sharp corners and other points of stress concentration are to be avoided.

7.6.9 Strong points are to be fitted in way of a transverse or longitudinal deck girder or beam to facilitate efficient distribution of the towing load.

7.6.10 The SWL of each towing arrangement component is to be no greater than 80 per cent of the design load applied.

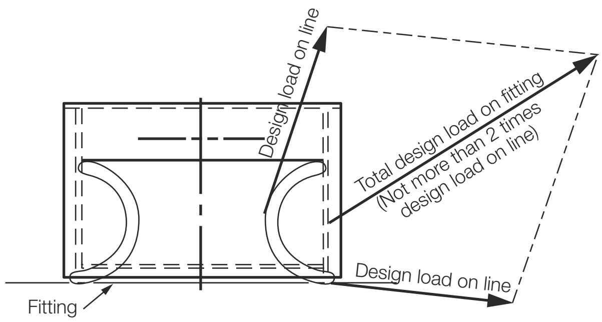


Figure 5.7.1 Design load applied to fittings

■ *Section 8*
Windlass and capstan design and testing

8.1 General

8.1.1 A windlass, capstan or winch of sufficient power and suitable for the size of anchor cable is to be fitted to the ship. Where Owners require equipment significantly in excess of Rule requirements, it is their responsibility to specify increased windlass power.

8.1.2 The windlass seating to be designed to loads no less than the maximum pull developed by the windlass.

8.1.3 Windlasses may be hand or power operated, subject to the requirements of *Vol 1, Pt 3, Ch 5, 8.2 Windlass design 8.2.3*

8.1.4 Where steel wire rope is used in lieu of chain cable, a suitable winch with sufficient drum capacity to store the length of wire rope fitted is to be provided.

8.1.5 The windlass, anchoring capstans and winches are to be of types approved by LR.

8.1.6 On ships equipped with anchors having a mass of over 50 kg, windlass(es) of sufficient power and suitable for the type and size of chain cable are to be fitted. Arrangements with anchor davits will be specially considered.

8.1.7 The design of the windlass is to be such that the following requirements or equivalent arrangements will minimise the probability of the chain locker or forecastle being flooded in bad weather:

(a) a weathertight connection can be made between the windlass bedplate, or its equivalent, and the upper end of the chain pipe, and
(b) access to the chain pipe is adequate to permit the fitting of a cover or seal, of sufficient strength and proper design, over the chain pipe while the ship is at sea.

8.2 Windlass design

8.2.1 The following performance criteria are to be used as a design basis for the windlass:

(a) The windlass is to have sufficient power to exert a continuous duty pull over a period of 30 minutes of:
   (i) For specified design anchorage depths up to 82,5 m:

Cable grade	Duty pull, P, in N
U1	$37{,}5 d_c^{\ 2}$
U2	$42{,}5 d_c^{\ 2}$
U3	$47{,}5 d_c^{\ 2}$

(ii) For specified design anchorage depths greater than 82,5m:

$$P_1 = P + (D_a - 82{,}5)\ 0{,}27 d_c^{\ 2} \text{ N}$$

where d_c is the chain diameter, in mm, D_a is the design anchorage depth, in m, P is the duty pull for anchorage depth up to 82,5 m and P_1 is the duty pull for the anchorage depths greater than 82,5

(a) The windlass is to have sufficient power to exert, over a period of at least two minutes, a pull equal to the greater of:

(i) short term pull: 1,5 times the continuous duty pull as defined in *Vol 1, Pt 3, Ch 5, 8.2 Windlass design 8.2.1*.

(ii) anchor breakout pull:

$$12{,}18 Wa + \frac{7{,}0 L_c d_c^{\ 2}}{100} \text{N}$$

where

L_c is the total length of chain cable on board, in metres, as given by *Table 5.4.1 Equipment - HHP Bower anchors and chain cables*

W_a is the mass of bower anchor (kg) as given in *Table 5.4.1 Equipment - HHP Bower anchors and chain cables*.

(b) In the absence of a chain stopper, the windlass, with its braking system in action and in conditions simulating those likely to occur in service, is to be able to withstand, without permanent deformation or brake slip, a load, applied to the cable, given by:

$$K_b d_c^{\ 2} \left(44 - 0{,}08 d_c\right) \text{ N}$$

where

K_b is given in *Table 5.8.1 Values of K_b*

The performance criteria are to be verified by means of shop tests in the case of windlasses manufactured on an individual basis. Windlasses manufactured under LR's Type Approval Scheme for Marine Engineering Equipment will not require shop testing on an individual basis.

(c) Where a chain stopper is fitted, the windlass braking system is to have sufficient brake capacity to ensure safe stopping when paying out the anchor and chain. It is the Master's responsibility to ensure that the chain stopper is in use when riding at anchor. At clearly visible locations on the bridge and adjacent to the windlass control position the following notice is to be displayed:

"The brake is rated to permit controlled descent of the anchor and chain only.

The chain stopper is to be used at all times whilst riding at anchor."

Table 5.8.1 Values of K_b

Cable grade	K_b	
	Windlass used in conjunction with chain stopper	Chain stopper not fitted
U1	4,41	7,85
U2	6,18	11,00
U3	8,83	15,7

8.2.2 Windlass performance characteristics specified in *Vol 1, Pt 3, Ch 5, 8.2 Windlass design 8.2.1* and *Vol 1, Pt 3, Ch 5, 8.7 Tests and trials 8.7.2* are based on the following assumptions:

(a) One cable lifter only is connected to the drive shaft.
(b) Continuous duty and short term pulls are measured at the cable lifter.
(c) Brake tests are carried out with the brakes fully applied and the cable lifter declutched.
(d) The probability of declutching a cable lifter from the motor with its brake in the off position is minimised.
(e) Hawse pipe efficiency assumed to be 70 per cent.

8.2.3 Hand-operated winches are only acceptable if the effort required at the handle does not exceed 150 N for raising one anchor at a speed of not less than 2 m/min and making about thirty turns of the handle per minute.

8.2.4 Winches suitable for operation by hand as well as by external power are to be so constructed that the power drive cannot activate the hand drive.

8.2.5 Calculations for torque transmitting components are to be based on 1500 hours of operation with a nominal load spectrum factor of 1,0. Alternatively, unlimited hours with a nominal load spectrum factor of 0,8 can be applied.

8.2.6 Where the available input torque exceeds the torque required for anchor breakout then torque overload protection is to be fitted.

8.2.7 An arrangement to release the anchor and chain in the event of windlass power failure is to be provided.

8.2.8 The maximum stress from load cases stated in *Table 5.8.2 Design load cases for windlass and chainstopper* is not to exceed the limits stated in *Table 5.8.3 Permissible stress for design load cases*.

Table 5.8.2 Design load cases for windlass and chainstopper

Load case	Condition	Note
1	Continuous pull	*See Vol 1, Pt 3, Ch 5, 8.2 Windlass design 8.2.1*
2	Overload pull	*See Vol 1, Pt 3, Ch 5, 8.2 Windlass design 8.2.1*
3	Brake holding load	*See Vol 1, Pt 3, Ch 5, 8.2 Windlass design 8.2.1*

Table 5.8.3 Permissible stress for design load cases

Stress	Load case	
	1 and 2	3
	Permissible stress	
Tension	0,8Y	0,9Y
Compression or bending	0,8Y	0,9Y
Shear	0,7Y	0,7Y
Combined	0,85Y	0,9Y
Note 1. Where a component is subjected to axial tensile, axial compressive, bending or shear stress, F_c is to be calculated in the normal manner.		
Note 2. Where a component is subjected to a combination of co-existent stresses, F_c is the combined stress which is to be calculated as follows:		
Combined bending and tension		
$F_c = 1{,}25 f_c + f_{bt}$		

Combined bending and compression

$$F_c = f_c + f_{bc}$$

Combined bending, tension and shear

$$F_c = \sqrt{\left(1,25 f_t + f_{bt}\right)^2 + 3 f_q^2}$$

Combined bending, compression and shear

$$F_c = \sqrt{\left(f_c + f_{bc}\right)^2 + 3 f_q^2}$$

where

F_c is the calculated stress

f_t is the calculated axial tensile stress

f_c is the calculated axial compressive stress

f_{bt} is the calculated maximum tensile stress due to bending about both principal axes

f_{bc} is the calculated maximum compressive stress due to bending about both principal axes

f_q is the calculated shear stress

Y is the specified 0,2 per cent proof stress for the material

8.2.9 The following criteria are to be used for gearing design:

(a) Torque is to be based on the performance criteria specified in *Vol 1, Pt 3, Ch 5, 8.2 Windlass design 8.2.1*.
(b) The use of an equivalent torque, T_{eq}, for dynamic strength calculations is acceptable but the derivation is to be submitted to LR for consideration.
(c) The application factor for dynamic strength calculation, K_A, is to be 1,15.
(d) Calculations are to be based on 1500 hours of operation.
(e) The static torque is to be 1,5 x T_n where T_n is the nominal torque.
(f) The minimum factors of safety for load capacity of spur and helical gears, as derived using ISO 6336 or a relevant National or International Standard acceptable to LR, are to be 1,5 for bending stress and 0,6 for contact stress.

8.2.10 Keyways are to be designed to a relevant National or International Standard acceptable to LR.

8.2.11 The maximum stress in brake components is not to exceed the permissible stress stated in *Table 5.8.3 Permissible stress for design load cases*.

8.3 Control arrangements

8.3.1 All control devices are to be capable of being controlled from readily accessible positions and protected against unintentional operation.

8.3.2 The maximum travel of the levers is not to exceed 600 mm if movable in one direction only, or 300 mm to either side from a central position if movable in both directions.

8.3.3 Wherever practical, the lever is to move in the direction of the intended movement. If this cannot be achieved, it is to move towards the right when hauling and towards the left when paying out.

8.3.4 For lever-operated brakes, the brake is to engage when the lever is pulled and disengage when the lever is pushed. The physical effort on the brake for the operator is not to exceed 160 N.

8.3.5 For pedal-operated brakes, the maximum travel is not to exceed 250 mm and the physical effort for the operator is not to exceed 320 N.

8.3.6 The handwheel or crankhandle is to actuate the brake when turned clockwise and release it when turned counterclockwise. The physical effort for the operator is not to exceed 250 N for speed regulation and 500 N at any moment.

8.3.7 When not provided with automatic sequential control, separate push-buttons are to be provided for each direction of operation.

8.3.8 The push-buttons are to actuate the machinery when depressed and stop and effectively brake the machinery when released.

8.3.9 The above mentioned individual push-buttons may be replaced by two ‘start’ and ‘stop’ push-buttons.

8.3.10 Control systems for windlasses are to comply with the requirements of *Vol 2, Pt 9, Ch 8, 5 Programmable electronic systems (PES)*.

8.3.11 Windlass motors are to be protected against overload, overspeed and overpressure, using appropriate safety techniques suitable for the intended installation.

8.4 Maintenance arrangements

8.4.1 Access is to be provided for inspection of reduction gears, bearings, brakes, etc.

8.4.2 Accessible manual lubrication points, including nipples, are to be provided for both for oil and grease, as applicable.

8.4.3 Gear-boxes are to be provided with adequate access arrangements for monitoring and replacing oil.

8.5 Protection arrangements

8.5.1 Where applicable, moving parts of windlass machinery are to be provided with suitable railings and/or guards to prevent injury to personnel.

8.5.2 Protection is to be provided for preventing persons from coming into contact with surfaces having temperatures over 50°C.

8.5.3 Steel surfaces not protected by lubricant are to be protected by a coating, in accordance with the requirements of a relevant National or International Standard acceptable to LR.

8.5.4 For arrangements of power transmission systems and relief requirements, *see Vol 2, Pt 7, Ch 5, 11.1 General 11.1.2*.

8.6 Marking and identification

8.6.1 Controls are to be permanently marked for identification, unless their functions are readily apparent. If required, instructions are to be permanently marked and readily visible.

8.7 Tests and trials

8.7.1 Where shop testing is not possible and Type Approval has not been obtained, calculations demonstrating compliance with *Vol 1, Pt 3, Ch 5, 8.2 Windlass design 8.2.1* are to be submitted together with detailed plans and an arrangement plan showing the following components:

- Shafting.
- Gearing.
- Brakes.
- Clutches.

8.7.2 During trials on board the ship the windlass is to be shown to be capable of:

(a) for all specified design anchorage depths: raising the anchor from a depth of 82,5 m to a depth of 27,5 m at a mean speed of 9 m/min.
(b) for specified design anchorage depths greater than 82,5 m, in addition to (a): raising the anchor from the specified design anchorage depth to a depth of 82,5 m at a mean speed of 3 m/min.

Following trials, the ship will be eligible to be assigned a descriptive note ‘Specified design anchorage depth. . . metres’ which will be entered in column 6 of the *Register Book*.

8.8 Seatings

8.8.1 The windlass is to be efficiently bedded and secured to the deck. The thickness of the deck in way of the windlass is to be increased, and adequate stiffening is to be provided, to the Surveyor’s satisfaction. The structural design integrity of the bedplate is the responsibility of the Builder and windlass manufacturer.

Section 9
Structural details

9.1 General

9.1.1 An easy lead of the cables from the windlass to the anchors and chain lockers is to be arranged. Where cables pass over or through stoppers, these stoppers are to be manufactured from ductile material and be designed to minimise the probability of damage to, or snagging of, the cable. They are to be capable of withstanding without permanent deformation a load equal to 80 per cent of the Rule breaking load of the cable passing over them.

9.2 Bulbous bow and wave piercing bow arrangements

9.2.1 The shell plating is to be increased in thickness at the fore end of the bulb and in other areas likely to be damaged by the anchors and chain cables. The increased plate thickness is to be the same as that required for plated stems by *Vol 1, Pt 6 Hull Construction in Steel*.

9.3 Hawse pipes and anchor recesses

9.3.1 Hawse pipes, bow rollers and other deck gear, of adequate size and construction, are to be provided for handling and securing the anchors and are to be efficiently attached to the structure and arranged to give an easy lead to the cable.

9.3.2 The hawse pipes are to be of sufficient size and thickness with a minimum diameter not less than 12 times the diameter of the chain cable. The arrangement is to give an easy lead for the cable to the windlass.

9.3.3 Hawse pipes and anchor pockets are to be of ample thickness and of a suitable size and form to house the anchors efficiently, preventing, as much as practicable, slackening of the cable or movements of the anchor being caused by wave action. The shell plating and framing in way of the hawse pipes are to be reinforced as necessary, *see Vol 1, Pt 3, Ch 5, 9.5 Local reinforcement 9.5.1*. Substantial chafing lips are to be provided at shell and deck. These are to have sufficiently large, radiused faces to minimise the probability of cable links being subjected to high bending stresses. Alternatively, roller fairleads of suitable design may be fitted. Where unpocketed rollers are used, it is recommended that the roller diameter be not less than eleven times the chain diameter. Where hawse pipes are not fitted, alternative arrangements will be specially considered.

9.3.4 The lines of the bow are to be taken into consideration when siting the anchor recesses for conventional bower anchors. Sufficient clearance of the flukes from the hull is to be maintained over the whole of the anchor run, above and below the water, considering the flukes in the most critical position. If a bow sonar dome is fitted, consideration is to be given to the positioning of the anchor recesses to reduce the possibility of the anchor chain rubbing on the dome when the anchor is in the deployed position.

9.4 Spurling pipes

9.4.1 Satisfactory means are to be provided to prevent inadvertent flooding of chain lockers.

9.5 Local reinforcement

9.5.1 The thickness of shell plating determined in accordance with the Rule requirements is to be increased locally by not less than 50 per cent in way of hawse pipes.

Section 10
Launch and recovery, berthing and dry-docking arrangements

10.1 Berthing loads

10.1.1 To resist loads imposed by tugs and berthing operations all structure within a 1,0 m strip centred 1,0 m above the deep waterline. It should be able to withstand the following pressure P_{b}:

$$= \quad P_{\mathrm{b}} = \left(\frac{g\,\Delta}{800}\right)\ \mathrm{kN/m}$$

where

Δ = deep displacement, in tonnes.

10.1.2 If L_R >200 m, or the ship is able to have significantly different loading conditions, the strip is to be taken from 1,5 m above the light waterline to 2,5 m above the deep waterline.

10.1.3 Ships with markings to indicate location of internal structure designed specifically for berthing purposes will be specially considered.

10.2 Dry-docking arrangements

10.2.1 Dry-docking arrangements are not explicitly covered in the Rules, *see Vol 1, Pt 3, Ch 1, 4.1 Submission of plans and data*. These requirements are intended to address the loads imposed on the vessel during dry-docking.

10.3 Dry-docking plan

10.3.1 In accordance with *Vol 1, Pt 6, Ch 1, 2.2 Plans to be submitted 2.2.6* a dry-docking plan is to be submitted as a supporting document. Consideration should be given throughout the design of a vessel to producing a dry-docking plan. The dry-docking plan should include, but not be limited to, the following information:

- The permissible locations of dock furniture;
- Maintenance and withdrawal envelopes;
- The arrangement of underwater fittings and openings.

The dry-docking plan should take into account multiple likely docking arrangements for maintenance and through-life support.

10.4 Dry-docking loads

10.4.1 Dry-docking a ship on blocks potentially imposes high vertical loads on the keel. For ships where the Rule length, L_R, exceeds 50 m, the strength of the keel and bottom structure is to be assessed.

10.4.2 Methods, other than those described here, for demonstrating that the strength of the keel and bottom structure is sufficient to withstand the loads imposed by dry-docking may be considered. Such methods are to be agreed with LR prior to the analysis being conducted.

10.4.3 For each dry-docking arrangement the stress and buckling behaviour of the bottom structure in way of the proposed dock blocks is to be assessed. The acceptance criteria given in *Table 5.10.1 Acceptance criteria* are not to be exceeded.

Table 5.10.1 Acceptance criteria

Structural Item	Allowable stresses, *see* Note		Minimum Buckling factor
	σ_e	τ	λ
Double bottom girders	0,75 σ_L	0,35 σ_o	1,2
Double bottom floors	0,75 σ_L	0,35 σ_o	1,1
Symbols			

σ_o = specified minimum yield stress of material. σ_o for steels having a yield stress above 355 N/mm^2 will be specially considered σ_L = $\frac{235}{k_L}$ N/mm^2 λ = factor against elastic buckling σ_e = von Mises equivalent stress = $\sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_y \sigma_x + 3\tau_{xy}^2}$	
Note In areas where the openings have not been modelled, the resulting shear stress and Von Mises stress is to be corrected according to the ratio of the actual to the modelled shear area. If the resulting stress levels exceed 90% of the specified allowable values, further study by means of fine mesh follow up models may be required. Von Mises stresses are to be recalculated on the basis of the corrected shear stresses.	

10.4.4 Where it is anticipated that there will be more than one typical dry-docking loading condition, the bottom structure is to be assessed for a representative number of loading conditions.

10.4.5 It is recommended that the block load distribution be derived by direct calculation using a full ship finite element model, constructed generally in accordance with the ShipRight SDA procedure for passenger ships. Where the dry-docking load distribution, F_{DL}, as defined in *Vol 1, Pt 3, Ch 5, 10.4 Dry-docking loads 10.4.6* becomes negative at any point, the block load distribution is to be derived by such direct calculations. The model is to be supported on grounded spring elements representing the proposed dry-docking arrangements. The spring element stiffness in the model should be representative of the combined block and capping stiffness. A sensitivity assessment should be carried out to ascertain the structural response to the spring constant used.

10.4.6 The following equation may be used to calculate the dry-docking load distribution, F_{DL}, between main transverse bulkheads acting on a keel block:

$$F_{DL} = \frac{W_c f_{bhd}}{(n-1)L_{kb}} + W_{oh} \text{ kN/m}$$

where

F_{DL} = dry-docking load distribution acting on a keel block, in kN/m

W_c = section weight between main transverse bulkheads, in kN

f_{bhd} = 2, for the keel blocks located adjacent to a main transverse bulkhead

= 1, elsewhere

n = number of keel blocks between main transverse bulkheads

L_{kb} = nominal keel block length, in metres

W_{oh} = weight increase per unit length due to an overhang, if applicable, *see Vol 1, Pt 3, Ch 5, 10.4 Dry-docking loads 10.4.8*.

10.4.7 For ships with an after end cut-up or significant rake of stem where there is considerable overhang, it may be assumed that the increase in load due to the overhang will extend a distance equal to twice the length of the overhang and will be distributed parabolically, *see Figure 5.10.1 Calculation of dock block loads in way of the after cut-up*.

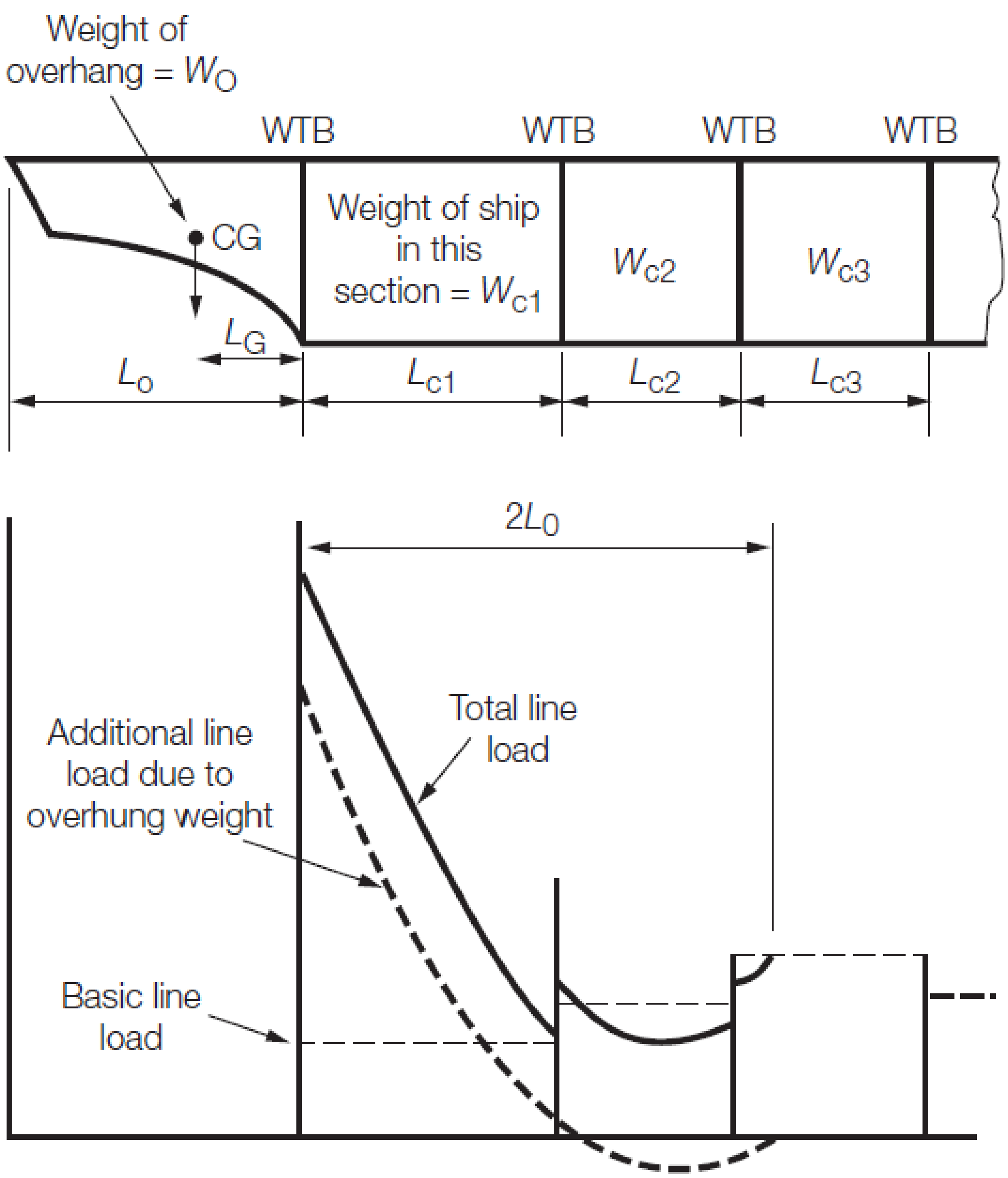


Figure 5.10.1 Calculation of dock block loads in way of the after cut-up

10.4.8 The increase in weight per unit length to be added due to an overhang, *see Vol 1, Pt 3, Ch 5, 10.4 Dry-docking loads 10.4.6*, is to be determined from the following equation:

$$W_{oh} = \frac{W_o K_{dl}}{L_o} \ kN/m$$

= *where*

W_{oh} = additional weight per unit length due to overhang, in kN/m

W_o = weight of overhang in kN

k_{dl} = $\left(1,5+2,25\frac{L_G}{L_o}\right)\left(\frac{X}{L_o}\right)^2-\left(4,5+6\frac{L_G}{L_o}\right)\left(\frac{X}{L_o}\right)+3\frac{L_G}{L_o}+3$

x = distance from the overhang, measured in metres from the mid-point of the last keel block

L_o = length of overhang, in metres

L_G = horizontal distance measured from the mid-point of the last keel block to the centre of gravity of the overhang, in metres.

10.4.9 When an overlap of the forward and aft overhang correction curves occurs, both curves are to be included. This will increase the possibility that blocks amidships will become unloaded, *see Vol 1, Pt 3, Ch 5, 10.4 Dry-docking loads 10.4.5*.

10.5 Launching loads

10.5.1 The launching loads are to be checked by the shipbuilder using conventional analytical methods appropriate to the method of launch. If via a slipway, the structure in way of the fore poppet should be suitable for the high loads that will be transmitted in this area. If adequate structure is not available, temporary stiffening is to be arranged.

10.5.2 The global strength of the hull girder is to be adequate under the loads imposed by launching, in particular for NS1 ships.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter is applicable to all ship types and components and the requirements are to be applied in conjunction with the relevant Chapters of *Vol 1, Pt 6 Hull Construction in Steel*

1.2 Classification notations

1.2.1 In addition to the hull class notations defined in *Vol 1, Pt 1, Ch 2 Classification Regulations*, ships complying with the requirements of this Chapter will be eligible to be assigned the additional optional class notations defined in *Vol 1, Pt 1, Ch 2 Classification Regulations*.

1.3 Information and plans required to be submitted

1.3.1 The information and plans required to be submitted are as specified in *Vol 1, Pt 6, Ch 1, 2.2 Plans to be submitted*, applicable to the particular ship type and in this Chapter where related to particular items and notations.

■ *Section 2* Structural Design Assessment

2.1 Structural Design Assessment notation – SDA

2.1.1 Where scantlings are primarily examined using finite element methods for both the overall and detailed structural capability of the ship using Lloyd's Register (hereinafter referred to as 'LR') approved procedures, the notation **SDA** (Structural Design Assessment) may be assigned and will be entered in the *Register Book*.

Section 3
Fatigue Design Assessment

3.1 Fatigue Design Assessment notation – FDA

3.1.1 Where the fatigue capability of the ship has been assessed using LR approved procedures, the notation **FDA** (Fatigue Design Assessment) may be assigned and will be entered in the *Register Book*.

Section 4
Construction Monitoring

4.1 Construction Monitoring notation – CM

4.1.1 The Construction Monitoring (**CM**) notation may be assigned if extended controls on structural alignment, fit-up and workmanship standards are applied to critical areas, as identified during the design of the ship. Construction Monitoring is applied primarily to verify the quality of workmanship required to improve the fatigue resistance of critical details, though other construction quality requirements can be specified in the CM plan.

4.1.2 The fatigue life of structural details can be adversely affected by a variety of factors, including workmanship defects. Criteria for workmanship defects can be considered in the CM plan. The most common factors that impact on fatigue are:

(a) Misalignment of structural members; i.e. poor fit-up;
(b) Welding defects;
(c) Materials defects;
(d) Stress concentrations resulting from incorrect geometry of structure, inadequate plate edge finish or generally poor manufacturing;
(e) Erroneous cut-outs due to inappropriate routing of systems;
(f) Discontinuity of structural members.

4.2 Identification of critical areas

4.2.1 A critical area is generally a structurally significant item or structural joint that has been subjected to an enhanced calculation or assessment. As a consequence, the performance of the item or joint will be influenced by the workmanship and fit-up in the building yard. In some areas, where there are high cyclic stresses, an enhanced workmanship and alignment standard is required in order to achieve the specified design hull fatigue life.

4.2.2 Critical areas will be identified by LR from the following assessments:

(a) Structural Design Assessment (SDA), specified in *Vol 1, Pt 3, Ch 6, 2 Structural Design Assessment*;
(b) Fatigue Design Assessment (FDA), specified in *Vol 1, Pt 3, Ch 6, 3 Fatigue Design Assessment*.

The **CM** notation is mandatory if the **SDA** or **FDA** notations are applied.

4.2.3 Critical areas may also be identified by LR from one of the following optional assessments. In general, these will be associated with reinforcement and alignment of specific critical joints; they will not be associated with general deformation criteria:

(a) Extreme Strength Assessment (ESA), specified in *Vol 1, Pt 6, Ch 4, 3 Extreme Strength Assessment, ESA*;
(b) Residual Strength Assessment (RSA), specified in *Vol 1, Pt 6, Ch 4, 4 Residual Strength Assessment, RSA*;
(c) Whipping Assessment (WH), specified in *Vol 1, Pt 4, Ch 2, 6 Whipping*.

4.2.4 In addition, critical areas may be identified by the designer, Naval Administration or Owner from one of the following:

(a) Known areas of high stress identified by structural engineers;
(b) Areas that have experienced failure on similar ships in service;
(c) Structures with specific alignment requirements; e.g. masts, shaft brackets.

4.2.5 The critical areas, locations and assessment criteria are to be detailed in the Construction Monitoring plan. The plan should also contain templates to be used to record specific alignment requirements. The CM plan may be supported by a high-stress key plan identifying critical regions on the ship.

4.2.6 Development of the CM plan is the responsibility of the designer; LR will identify the critical locations to be subjected to monitoring, following appraisal of the assessments identified in *Vol 1, Pt 3, Ch 6, 4.2 Identification of critical areas 4.2.2* and *Vol 1, Pt 3, Ch 6, 4.2 Identification of critical areas 4.2.3* above. In general, areas with stress ranges greater than σ_{WS}, *see Vol 1, Pt 6, Ch 4, 2.2 Bending strength 2.2.3*, and areas where general or detailed fatigue analysis has been undertaken will be listed in the appraisal documentation. LR may develop the CM plan on behalf of the designer, if so requested.

4.2.7 It is recommended that the areas for Construction Monitoring be identified and the criteria developed in a workshop with the Owner, Naval Administration, Builder and LR.

4.3 Construction monitoring criteria

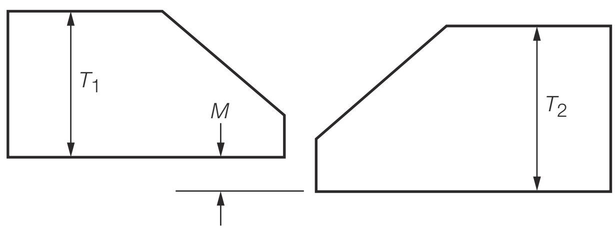
4.3.1 Critical areas are to be assigned an alignment criterion, as given in *Vol 1, Pt 3, Ch 6, 4.3 Construction monitoring criteria 4.3.2*, based on the significance of the item and requirement from which it was derived. LR will review and agree the criterion assigned before construction commences.

4.3.2 **Normal alignment** is assigned to structure which requires an enhanced level of survey above the normal survey requirement but does not require enhanced levels of alignment above the agreed production standard, such as the Naval Survey Guidance for Steel Ships:

(a) Structure will be inspected by the Builder, before welding, for compliance with the general shipbuilding tolerances laid down in the agreed production standard.
(b) A representative sample of alignment measurements will be undertaken by LR during the survey to confirm compliance with the agreed production standard.
(c) Where there are non-compliances, the relevant shipyard department will be requested by LR to undertake full measurements and to produce a report for review by LR which details the non-compliances.

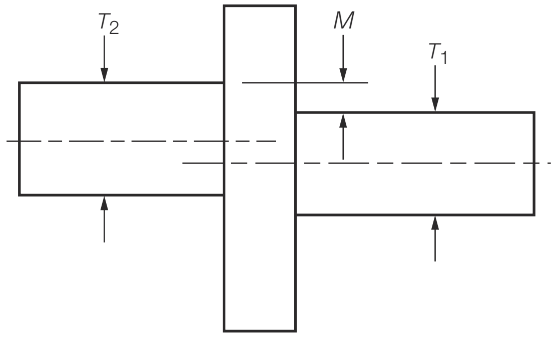
4.3.3 **Enhanced alignment** is assigned where critical areas have enhanced alignment requirements to maintain structural performance:

(a) The relevant shipyard department will be required to provide a report, based on templates in the CM plan, detailing the achieved alignment at each location.
(b) LR will review the alignment report and request check measurements as necessary to confirm the results.
(c) The maximum allowable misalignment between the interconnection of structural members is to be 15 per cent of the thinner of the members being connected. This alignment criterion is to be applied where longitudinally effective structure is butted; e.g. plating at ring butts, longitudinal butts, *see Figure 6.4.1 Alignment criterion*.
(d) For all cruciform joints, the maximum allowable misalignment between the interconnection of structural members is to be 20 per cent of the thinner of the members being connected. This alignment criterion is to be applied where there is alignment through a thickness; e.g. intercostal longitudinal bulkheads through a transverse bulkhead, bilge keel plate alignment with internal structure through shell plating, *see Figure 6.4.2 Cruciform joints*.



T_1 = thickness of the thinner member
T_2 = thickness of the thicker member
M = misalignment is not to be greater than $0{,}15T_1$, from moulded line

Figure 6.4.1 Alignment criterion



T_1 = thickness of the thinner member
T_2 = thickness of the thicker member
M = misalignment is not to be greater than $0,2T_1$

Figure 6.4.2 Cruciform joints

4.3.4 **Specific alignment** is assigned where there are specific alignment criteria identified by the designer which need to be verified by LR:

(a) the relevant shipyard department will be required to provide a report detailing the achieved alignment at each location;
(b) LR will review the alignment report and request check measurements as necessary to confirm the results;
(c) the alignment criteria and templates, where appropriate, are to be defined by the designer for each critical area defined.

4.3.5 **Close-up inspection** is assigned to structure which has no specific alignment requirement but requires an increased level of inspection; for example, to verify correct plate thickness or maximum permitted plate deformation. Close-up inspection may be required to verify a particular or unusual structural feature:

(a) Structure will be subject to an enhanced close-up visual inspection by LR Surveyor(s).
(b) Dry surveys should identify where units or compartments contain construction monitoring points. These are to be identified by the Builder as a specific witness point.

4.3.6 Non-destructive examination, in addition to the general levels of NDE required in *Vol 1, Pt 6, Ch 6 Material and Welding Requirements*, may be specified by the designer for critical areas, which LR will verify:

(a) The relevant shipyard department will be required to undertake the additional NDE required at each location and record the results.
(b) LR will review and audit the NDE measurements as necessary to confirm the results.

4.4 Construction Monitoring survey

4.4.1 Construction Monitoring is a process for monitoring workmanship standards and alignment in critical areas. It is the Builder's responsibility to carry out the necessary checks and document the results for relevant critical locations, irrespective of the Surveyor(s) attendance at hold points. Shipyard personnel are responsible for the inspection and recording of all CM requirements, in accordance with the approved CM plan.

4.4.2 LR will provide third party inspection to confirm that the critical areas to be covered by CM conform to the required/agreed standards based on check inspections and audit activities. Where LR undertakes a CM inspection to verify the implementation of the CM plan, it will cover:

(a) weld specification in terms of type, size and finish/treatment, including:
    (i) fit-up and alignment before commencement of welding;
    (ii) alignment after application of first root run;
    (iii) back gouging;
    (iv) final welding and alignment;
    (v) stress relief grinding of weld profile (where required for enhanced fatigue performance);
(b) the continuity of structural members, where required;

(c) plate edge radius and roughness;
(d) joints for radius and tapering;
(e) openings and penetrations for radius corners.

4.4.3 LR will review all of the specific CM records, as defined in *Vol 1, Pt 3, Ch 6, 4.3 Construction monitoring criteria*, and in a few cases request that measurements be presented. It is not intended that the attending Surveyor(s) witness each stage of the fabrication process for every critical area, except during the early stages of construction whilst the process is being established.

4.4.4 CM activities will generally be undertaken in conjunction with routine dry surveys required for all construction units. A few specific CM items require measurement by the shipyard; these are described as Enhanced or Specific Alignment.

4.4.5 Non-compliances will not be permitted in the critical areas identified within the CM plan. Where defects are identified within defined critical sections, LR is to agree the remedial action to be taken with the Shipbuilder before rectification is commenced.

4.4.6 On satisfactory completion of all surveys and measurements, LR Surveyor(s) will recommend the assignment of the CM notation.

■ *Section 5* Ship Event Analysis

5.1 Ship Event Analysis – Class notations SEA(HSS-n), SEA(VDR), SEA(VDR-n)

5.1.1 At the Owner's request, and in order to enhance safety and awareness on board during ship operation, provisions can be made for the following systems:

(a) A hull surveillance system that monitors the hull girder stresses and motions of the ship and warns the ship's personnel that these levels or the frequency and magnitude of slamming motions are approaching a level where corrective action is advisable.
(b) A voyage data recorder system that can record the ship's control, navigational, operational and hull response information. This information is recorded and stored in a protective containment unit to enable the analysis of any marine or other incidents.

5.1.2 Where a hull surveillance system is fitted the class notation **SEA(HSS-n)** will be assigned. Where a voyage data recorder system is fitted the class notation **SEA(VDR)** or **SEA(VDR-n)** will be assigned. The extension **-n** signifies the number of fitted strain gauges connected to the system. The appropriate class notation(s) will be entered in column 6 of the *Register Book*, *see also Vol 1, Pt 1, Ch 2, 3.9 Machinery and Engineering Systems notations 3.9.4* of the Rules for Ships.

■ *Section 6* Enhanced Scantlings

6.1 Enhanced Scantlings – ES

6.1.1 Where scantlings in excess of the approved Rule requirement are fitted at defined locations as a corrosion margin or for other purposes as specified by the Owner, a notation, **ES**, 'Enhanced Scantlings', will be assigned. It will be accompanied by a list giving items to which the enhancement has been applied and the increase in scantling. For example, the item 'bottom shell (strakes A, B, C, D) + 2' will indicate that an extra 2 mm has been fitted to the bottom shell of the ship for the particular strakes listed, *see also Vol 1, Pt 6, Ch 6, 2.10 Corrosion margin*. In addition, the plans submitted for approval are to contain the enhanced scantling, together with the nominal thickness less the enhancement, adjacent and in brackets.

Section 7
Protective Coatings

7.1 General

7.1.1 It is recommended for all ship types that all salt-water spaces having boundaries formed by the hull envelope have a corrosion protection coating applied.

7.1.2 It is recommended that consideration be given to the effective corrosion protection of other internal spaces and external areas by the use of a suitable protective coating system.

7.2 Protective Coating in Water Ballast Tanks – PCWBT

7.2.1 If the Owner so wishes, a notation, **PCWBT** 'Protective Coating in Water Ballast Tanks', will be entered in the *Register Book* to indicate that the ship's water ballast tanks are coated and that the coating remains efficient and well maintained. If the coatings have broken down, particularly at more critical areas, and no effort is being made to maintain the coatings, then this notation will be placed in parentheses, i.e. (**PCWBT**). In either case the date of the last survey will be placed in parentheses after the notation.

7.3 ShipRight ACS notations

7.3.1 The Anti-Corrosion System notation, **ShipRight ACS (B)**, will be assigned to Naval vessels, at the Owner's request, when protective coating systems have been applied to water ballast tanks during construction, in accordance with the *ShipRight Anti-Corrosion System Notations for Naval Ships procedure*.

7.3.2 The notation **ShipRight ACS (B)** indicates that the protective coating systems for water ballast tanks has been applied in accordance with IMO regulations; however, it is only available to new-build ships. The **PCWBT** notation may be applied to existing ships when in compliance with the applicable provisions.

Section 8
Hull Condition Monitoring

8.1 Hull Condition Monitoring – HCM

8.1.1 Where an Owner adopts the LR Hull Condition Monitoring Scheme the notation **HCM**, 'Hull Condition Monitoring' will be entered in the *Register Book*.

8.1.2 This notation will indicate that a computer software system for on-board recording of ship surveys is available aboard ship.

Section 9
Ship Emergency Response Service

9.1 Ship Emergency Response Service – SERS

9.1.1 This service, offered by LR, provides a rapid computer assisted analysis of a damaged ship's stability and damaged longitudinal strength in the event of a casualty to the ship.

9.1.2 Where an Owner adopts this service, the notation **SERS**, 'Ship is registered with LR's Ship Emergency Response Service', will be entered in the *Register Book*.

■ *Section 1* General requirements

1.1 General

1.1.1 This section is aimed primarily at assessing structure such that it can resist the military loads imposed upon it, however it is essential in naval ship design to consider the effects an item of equipment or structure can have on a variety of parameters. For example a winch support and mount may adequately resist the forces imposed upon it during normal operation and absorb shock loads but have an unacceptably high noise or radar signature.

1.1.2 Chapter 1 gives guidance on some of the additional issues that the designer must consider in the design of a naval ship. Whilst it does not always give the definitive answer on these topics, it will help identify the impact of structural design on the subject. An example is radar signature reduction. The guidance gives the geometric properties to avoid but it will not give detail on radar absorbent coatings.

1.1.3 Information is classified in two types. Firstly, design guidance for which further approval has to be sought once a suitable standard is specified, and secondly, design requirements which have to be met as part of the ✠ **100A1** notation or a specific notation such as **LA(N)**.

1.2 Plans

1.2.1 Plans are to be submitted showing the manner in which the requirements have been met and the location of the structure within the vessel for those features that have either a special notation or are required as part of the notation ✠ **100A1** or ship type.

1.2.2 Details on the loadings applied to individual items, and by these items to the support structure are to be included. In some cases stiffness requirements will also need to be included, e.g. mast mounted equipment.

1.2.3 Plans, and where requested, calculations should be submitted for the following features as appropriate:

- Replenishment at sea arrangements.
- Aircraft and vehicle tie down arrangements.
- Movable decks, ramps and lifts.
- Masts and support arrangements.
- Towed array or towed body arrangement.
- Weapon recoil and thrust loadings.

1.2.4 Arrangements for the following features are to be included with the hull structural plans listed in *Vol 1, Pt 6, Ch 2, 2 Structural design*. In addition calculations are to be supplied where requested:

- Vehicle decks.

- Helicopter decks.
- Berthing.
- Docking loads.
- Beach landing or grounding.
- Holding down arrangements.

1.2.5 Plans and supporting calculations should be submitted for the following notations:

- External blast (**EB1, EB2, EB3, EB4**).
- Internal blast (**IB1, IB2**).
- Fragmentation (**FP1, FP2**).
- Small arms protection (**SP**).
- Underwater explosion (Shock) (**SH**).
- Whipping (**WH1, WH2, WH3**).
- Residual strength (**RSA1, RSA2, RSA3**).

1.3 Signature

1.3.1 A naval vessel will generally require some form of signature control and the operational requirement will determine the extent to which this is necessary. Signature control can be achieved using a variety of methods both active and passive. This section deals with the passive methods that structure can influence.

1.3.2 With good structural design the signature of the vessel can be controlled to a certain degree with little cost. The methods listed in *Table 1.1.1 Ship signatures* can help achieve this.

1.3.3 It is beyond the scope of the Rules to provide further detail on signatures, however on request, Lloyd's Register (hereinafter referred to as 'LR') is able to provide information on suitable organisations who are able to give specialist advice as necessary.

1.3.4 Special features notations for signature control will not normally be assigned. Some of the above features will form part of the Naval Ship notation ✠ **100A1 NS** and are detailed in *Vol 1, Pt 4, Ch 1, 3 Military distinction notations*.

Table 1.1.1 Ship signatures

Signature	Simple methods of control using hull construction
Above water	
Visual	Camouflage paint
Infrared	Careful positioning of exhaust outlets
Radar cross-section	Structural shaping
Unintentional electro-magnetic emissions	Use of steel plating (Faraday cage)
Under water	
Self noise	Fairness of hull, low vibration
Radiated noise	Low vibration
Magnetic field	Non-ferrous materials Degaussing
Electric field	Attention to earth paths
Wake	Hull form, propeller design

1.4 Materials and welding

1.4.1 In addition to the requirements of *Vol 1, Pt 6, Ch 2 Design Tools*, ships having the following military distinction notations are to comply with the requirements of this section for the designated areas unless specified otherwise. The requirements apply to plates, stiffeners, fillet welds, butt welds and welded attachments:

- **EB1, EB2, EB3, EB4** Above water portion of the hull, superstructure and upper decks assessed against external blast requirements.
- **IB1, IB2** Blast bulkheads.
- **SH** Hull envelope plating.
- **WH1, WH2, WH3** Shear strake, stringer plate (including margin angle), bilge strake, keel plate, garboard strake and hull inserts.
- **RSA1, RSA2, RSA3** Shear strake, stringer plate (including margin angle), bilge strake, keel plate, garboard strake and hull inserts.

1.4.2 Crack arresting strakes of minimum Grade E are to be fitted in the following locations, from 0,2L_R to 0,8L_R, according to the notation assigned:

- **SH** Shear strake, stringer plate (including margin angle), bilge strake, keel plate, garboard strake and hull inserts in these areas.
- **WH1, WH2, WH3** Shear strake, stringer plate (including margin angle), bilge strake, keel plate, garboard strake and hull inserts in these areas.
- **RSA1, RSA2, RSA3** Shear strake, stringer plate (including margin angle), bilge strake, keel plate, garboard strake and hull inserts in these areas.

Where the hull envelope is made entirely from Grade D steel, crack arresting strakes of minimum Grade E need not be fitted in the specified locations.

1.4.3 Generally for joints between steels of different strength levels the welding consumable may be of a type suitable for the lesser strength.

1.4.4 For joints between steels of different toughness levels, the welding consumable is to be of a type suitable for the higher grade being connected.

1.4.5 The consumable used is to comply with the requirements of *Table 1.1.2 Welding consumable grade*. Other grades of steel will be specially considered, but in general, the toughness in the upward vertical direction is not to be significantly less than that of the parent plate, measured in the direction of rolling.

Table 1.1.2 Welding consumable grade

Steel grade	Normal electrode grade	Military requirement grade
A	1	1
AH32	1Y	2Y
AH36	1Y	2Y
AH40	2Y40	2Y40
B	2	2
D	2	3
DH32	2Y	3Y
DH36	2Y	3Y
DH40	3Y40	3Y40
E	3	4
EH32	3Y	4Y

EH36	3Y	4Y
EH40	4Y40	4Y40

1.4.6 Where armour plating consisting of steels with a specified tensile strength of 1000 MPa or above is integrated into the ship's structure by welding, consideration should be given to the susceptibility of these materials to hydrogen cracking. The use of normal strength or higher strength steel of toughness grade D or higher in terms of Charpy V-notch fracture toughness should be considered as an intermediate transition material where the adjacent material is not already of this grade.

1.4.7 The proposed welding procedures are to be submitted for review, and are to be chosen to minimise the risk of hydrogen cracking. The following is recommended:

(a) The use of welding consumables and electrodes with low hydrogen content (less than 5 ml/100 g of deposited weld metal).
(b) The weld preparation and welding apparatus, consumables and electrodes are to be clean, dry and free from other sources of hydrogen such as lubricants and grease.
(c) Controlled preheat, interpass temperatures, cooling rates and post-heat treatment chosen in accordance with manufacturers' guidance and recognised welding standards.
(d) Weld sequence chosen to minimise the formation of residual stresses.
(e) The use of welding consumables of a higher strength than necessary should be avoided.
(f) Non-destructive examination should not be carried out before a period of 48 hours has elapsed from the time welding is completed.

1.4.8 The use of mechanical fasteners to secure armour plating should be considered as a means of removing the risk of hydrogen embrittlement as a result of the welding process. Where higher strength steel fasteners with Vickers hardness above 320 HV are used, consideration should also be given to the susceptibility of these materials to hydrogen cracking.

■ *Section 2* Survivability

2.1 General

2.1.1 Survivability is defined as the probability that a ship can remain operational to some degree following an attack. The elements of whole ship survivability are shown in *Figure 1.2.1 Whole ship structural survivability*. Survivability is divided into two main aspects:

- Susceptibility, the probability of a threat acquiring, reaching and detonating on a ship.
- Vulnerability, the probability that a ship will be able to survive a successful attack and operate at a certain level.

Survivability is normally calculated as the product of susceptibility and vulnerability. Recoverability is an important aspect as it has a significant influence on the vulnerability of the overall ship as a system. It can be defined as a measure of the ability of the ship to reach a particular level of operation higher than that immediately following the hit. A variety of levels of operation required following damage can be defined, *see Vol 1, Pt 4, Ch 1, 2.2 Vulnerability*

2.1.2 Generally there are four basic phases in the classification of naval ships with respect to survivability:

- Concept phase.
- Assessment phase.
- Build phase.
- Maintenance phase.

2.1.3 The **concept phase** is not normally part of classification and is a discussion between the Owner, Naval Administration, designer and those specialists able to perform the appropriate calculations. It is used to identify the potential threats, requirements for the ship structure, machinery and systems with respect to those threats.

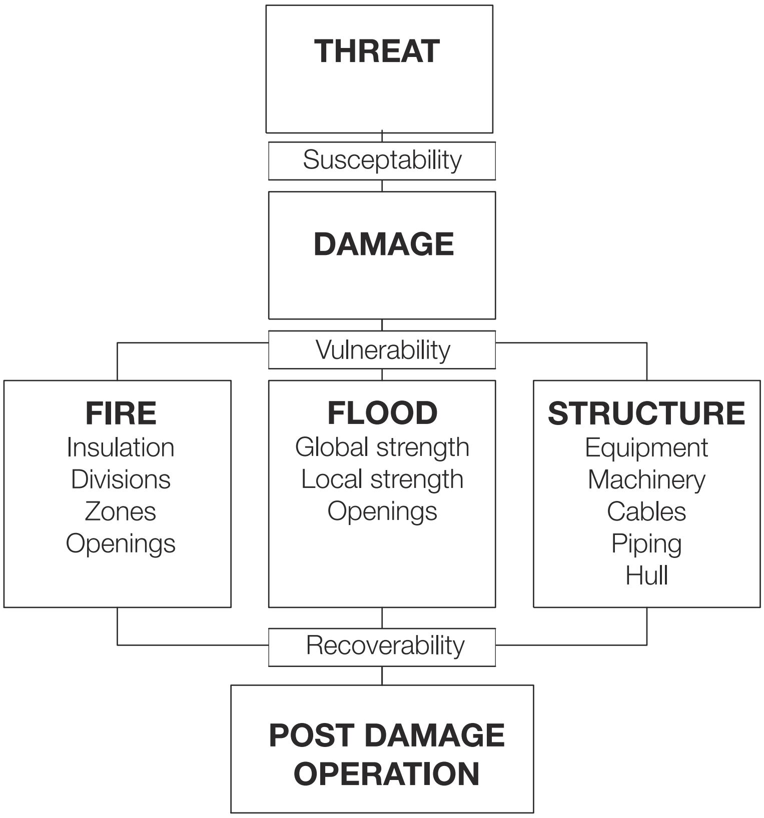


Figure 1.2.1 Whole ship structural survivability

2.1.4 The **concept phase** will apply all of the elements shown in *Figure 1.2.1 Whole ship structural survivability*:

(a) Identification of the threat is first and this is usually determined for current and future threats. Several threats will be identified which affect the ship in a variety of ways, they may be underwater or above water, far field, close in, or contact weapons. Typical threat groups are given in *Table 1.3.1 Relationship between notations*.

(b) The susceptibility is the ability of the threat to reach the ship and detonate and is a function of the capability of the threat, the ship's signatures and the ship's defence systems. Various computer codes and simulations are available for determining the susceptibility of a hull and the capability of weapon systems. Consideration should be given to the degradation of a threat by a ships defence systems.

(c) If a threat detonates, damage may result. The extent and amount of damage is a function of the vulnerability of the ship, *see Vol 1, Pt 4, Ch 1, 2.2 Vulnerability*. A vulnerability assessment may be used to determine the consequences of the threat detonation. The consequences are likely to be in the form of fire, flood and physical damage as shown in *Figure 1.2.1 Whole ship structural survivability*. The assessment tools used in the design stage for vulnerability analysis generally employ simple design formulae which are then verified during the assessment phase.

(d) The consequences of damage can be limited through recoverability, the ability to repair damage to structure, equipment and systems. This is mainly an operational matter though it will have an impact on ship design. Damage control operational procedures will make certain demands on structure and equipment.

2.1.5 It is beyond the scope of the Rules to provide further detail on the concept phase. However on request, LR is able to provide details of suitable organisations who are able to give specialist advice as necessary.

2.1.6 The **assessment phase** looks in more detail at the vulnerability of the ship and uses explicit calculations to assess the capability of the ship based upon the relevant effects of threats such as blast pressure or fragment size. It is not necessary to define the actual weapon, just the consequences or effects of threats. A threat can produce a variety of effects, the manner in which the rules currently address these effects is detailed in *Vol 1, Pt 4, Ch 2 Military Load Specification*. In naval ship classification, notations are used to donate that a calculation for a particular threat has been reviewed. Currently, these are

concerned with structural aspects only, though some aspects of machinery are indirectly addressed through other notations such as propulsion machinery redundancy, **PMR**, steering gear machinery redundancy, **SMR** and fire safety, **FIRE**.

2.1.7 The **build phase** ensures that the requirements of the assessment phase are put in place on board the ship. It is identical to the normal classification requirements for construction, installation and testing of structure and equipment under LR survey, verifying that the correct materials, welding fabrication and testing procedures are used.

2.1.8 The **maintenance phase** is applied by maintaining a ship in class through life. It verifies that the original standard to which the ship was built is maintained and that any new rule requirements are implemented. It also verifies that modifications to the ship do not compromise the integrity of the structure, equipment or systems.

2.1.9 It is the responsibility of the Naval Administration to ensure that each of the phases is implemented, to define the requirements that are to be met and advise the Owner on the manner in which particular threats can be dealt with.

2.2 Vulnerability

2.2.1 The resistance of a vessel to loadings from military threats can be described by the term vulnerability which is the probability that once hit by a specified threat a vessel will lose capability.

2.2.2 This Chapter deals separately with the effects of a threat on the structure but when considering the total vulnerability of the ship it will be necessary to combine all the effects of a weapon detonation to determine the total damage to the ship as a system. This is normally done very early in the design stage at a low level of complexity, *see Vol 1, Pt 4, Ch 1, 2.1 General 2.1.4* Several computer codes are available to determine the consequence of weapon threats on the ship system.

2.2.3 The damage to a ship is likely to occur by three mechanisms; fire, flood and physical damage, *see Figure 1.2.1 Whole ship structural survivability* The direct effect of threats on the ship's crew is not included in this Section but some features such as shelter stations and CBRN protection will reduce the risk. Indirect damage caused by the threat should also be considered and a vulnerability analysis can be used to site magazines such that they are offered the maximum protection.

2.2.4 The methods used to control the spread of fire will have an effect on structural design, materials, fire insulation, fire divisions and openings, and must all be considered. One method used to control the spread of fire is zones and some guidance on the philosophy and structural requirements are provided in *Vol 1, Pt 4, Ch 1, 7 Design guidance for nuclear, biological and chemical defence*. However, the precise requirements for fire detection, protection and extinction are to be provided in the specified fire safety standard(s). Where this is examined by LR in accordance with *Vol 1, Pt 1, Ch 2, 3.10 Other notations 3.10.7* a **FIRE** notation may be assigned. Other methods include the use of smoke tight boundaries, insulation and fire-fighting systems.

2.2.5 The stability of a vessel and flooding following damage is not covered in this Chapter. The specified subdivision and stability standard, should define the extent of damage that the vessel is required to survive and remain stable. All structure and watertight closing appliances will need to be assessed to this level. *Vol 1, Pt 3, Ch 1, 5 Definitions* defines how the minimum extent of watertight subdivision is to be determined. *Vol 1, Pt 3, Ch 4 Closing Arrangements and Outfit* contains details on requirements for closing appliances. For such an extreme event as flooding, plastic type analysis is appropriate for watertight structure and this is recognised in the relevant rule requirements.

2.2.6 For the hull, the effect of the threat can be limited in two ways:

- Ensuring that there is adequate global strength following damage using a residual strength analysis. Where appropriate a whipping analysis may also be necessary.
- Ensuring that local structure can contain the threat or limit the damage. Individual items of structure can be hardened or strengthened in certain areas to achieve this.

2.2.7 Physical damage may occur to cables, piping, equipment and machinery, and other systems. The duplication or protection of these items is dealt with in *Vol 2, Pt 1, Ch 3, 4.9 Military requirements*. Where protection is required, e.g. armour, the impact on the structural design of the hull is to be considered.

2.2.8 Different levels of vulnerability can be represented, as illustrated in *Figure 1.2.2 Vulnerability contours for a given threat level*Each will have different acceptance criteria for the hull structure. For an internally detonating threat, the increasing levels can be visualised as a threat of increasing magnitude rather than increasing distance.

2.2.9 Level A is that, closer than which, the hull structure will fail due to the detonation of a threat. The failure can occur in a number of ways as detailed in *Vol 1, Pt 4, Ch 2 Military Load Specification*. At this level the assessment will normally be performed using plastic criteria which will result in permanent deformation. The ship may no longer function effectively but it should remain afloat and not rupture or fail catastrophically.

2.2.10 Level B is that, closer than which, the majority of the ship's machinery and equipment is damaged such that it will not operate effectively and the ship can no longer continue to navigate. The hull must therefore not deform permanently and elastic assessment criteria may be necessary to determine the global strength of the hull (local deformation may be sustained).

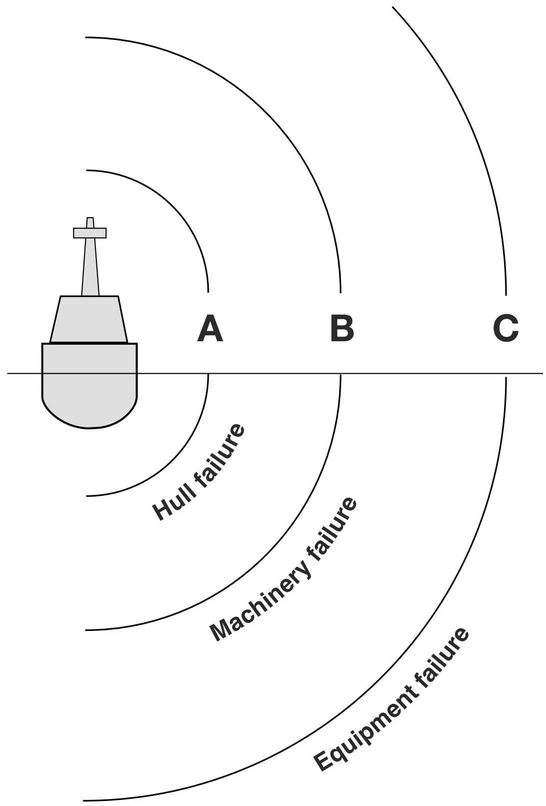


Figure 1.2.2 Vulnerability contours for a given threat level

2.2.11 Level C is that, closer than which, the ship's weapon systems begin to fail and the vessel is no longer able to operate with full effectiveness. Normally the global and local criteria would be assessed against elastic criteria.

2.2.12 Levels B and C for underwater threats are primarily dealt with by adopting a suitable shock policy for the ship.

2.2.13 It is the responsibility of the Owner to specify the levels at which these should be set. In theory, they could be made to be coincident but this would provide little reserve within the vessel for recovery by damage control and repair. Conversely, they should not be set too far apart as this represents unnecessary armament and strengthening which is not effectively protecting the equipment and machinery from attack.

2.2.14 For an assessment of a threat which also produces effects on machinery, two structural calculations may have to be performed. One at the equipment level of failure using failure criteria that result in little or no deformation (plating only for example) and one approaching a structural failure level using ultimate strength or plastic collapse criteria. The requirements in *Vol 1, Pt 4, Ch 2 Military Load Specification* generally deal with ultimate strength or plastic criteria, the conventional rule calculations in *Vol 1, Pt 6, Ch 2 Design Tools* and *Vol 1, Pt 6, Ch 5 Structural Design Factors* set elastic failure criteria. For normal naval ship construction, the hull is usually able to withstand the threat level at which equipment and systems fail with little or no permanent deformation, though some check calculations may be necessary on critical areas.

Section 3
Military distinction notations

3.1 General

3.1.1 By its very nature a naval ship will be required to face and resist a variety of threats and it will be necessary to incorporate particular features to address those threats.

3.1.2 Some of the features required are already incorporated in the notation ✠ **100A1 NS.** However, where the operational requirement demands, additional or specific levels of performance, special features notations such as those listed in *Vol 1, Pt 1, Ch 2, 4 Surveys – General* may be assigned showing protection against the effects of a particular threat.

3.1.3 Unless specifically requested these notations will be assigned at an appropriate level which will remain confidential to the Owner. It is the responsibility of the Owner to specify the threat levels suitable for their requirements. The agreed threat levels will not appear in the Register Book or be published in any other form. Only the notation ✠ **MD** will be used to show that some military features have been incorporated and constructed in accordance with LR's *Rules and Regulations for the Classification of Naval Ships.*

3.1.4 A distinction is made between:

- levels of threat, describing the magnitude of the missile, torpedo, mine or bomb; and
- method of analysis which may be performed at differing levels of complexity.

3.1.5 In an effort to establish links between the different military loads, default levels of threat have been assigned. A distinction is made between levels of above water and underwater threats, as certain ships may be at greater risk from one or the other depending upon their operational requirements. They are summarised in *Table 1.3.1 Relationship between notations*.

3.1.6 In addition to the hull class notations defined in *Vol 1, Pt 1, Ch 2 Classification Regulations*, ships complying with the requirements of this Chapter will be eligible to be assigned the additional class notations defined in *Vol 1, Pt 1, Ch 2, 2.2 Definitions 2.2.2* and *Vol 1, Pt 1, Ch 2, 2.2 Definitions 2.2.4* or descriptive notes as defined in *Vol 1, Pt 1, Ch 2, 2.2 Definitions 2.2.7*.

3.2 Above water threats

3.2.1 As described in *Table 1.3.1 Relationship between notations* the external blast notation is normally independent of the internal blast and fragmentation notations as the threats that produce a survivable blast effect usually have a reasonable stand off. Typically, significant blast loading will arise from externally detonating threats such as far field nuclear at large stand offs and fuel air explosions at moderate stand offs. For an externally detonating conventional weapon, the blast will normally be insignificant but there will usually be a fragmentation threat. The external blast notation may also be independent of the residual strength notation unless the plastic deformation from an external blast renders certain structure ineffective with respective to global strength. For example a superstructure which contributes to longitudinal strength.

Table 1.3.1 Relationship between notations

	Above water weapons								Underwater weapons			
	Small arms	Shell or projectile		Missile		Bomb			Mine or charge		Torpedo	
	Contact	Contact	Proximity	Contact	Proximity	Contact	Proximity	Far field (2)	Contact	Proximity	Contact	Proximity
SP	R	O										
FP		R	R	R	R	R	R					
IB		R		R		R						
EB			R		R		R	R				
SH									R	O	R	O

WH										R		R
RSA		O	O	R	O	R	R	R	R		R	
Symbols												
R = Required threats to be considered in the absence of a specific requirement. O = Optional threats to be identified by the Owner and dependent on the characteristic of the threat.												
Note 1. It remains the responsibility of the Owner to determine the appropriate military notation and the appropriate levels of threat and analysis. Note 2. For nuclear threats, consideration should be given to CBRN requirements for structure, see *Vol 1, Pt 4, Ch 1, 7 Design guidance for nuclear, biological and chemical defence*, filtration and ventilation. The ability of the structure to screen an electromagnetic pulse should also be considered.												

3.2.2 Usually, both internal blast and fragmentation will result from an internally detonating threat and are therefore linked, for example, a missile threat as shown in *Table 1.3.1 Relationship between notations*. For a particular threat it is recommended that both fragmentation and internal blast assessments will be made to the same level of threat for the structure adjacent to the point of detonation. Consideration should be given to the precise nature of the blast loading and fragmentation pattern of the threat.

3.2.3 If transverse bulkheads are used to limit the longitudinal spread of damage then the decks and side shell will probably be damaged such that a residual strength assessment is required to ensure that the global strength is not compromised. This should be to the same threat level as the internal blast threat. Longitudinal blast resistant bulkheads, box girders or service tunnels could be used to maintain the longitudinal effective material of the hull girder.

3.2.4 A residual strength assessment of the above water structure can be carried out for any threat level under any threat, independently of the other above water threat notations. This is because the ship may still retain function even though it has not been specifically armoured against the internal blast or fragmentation arising from such a threat. The residual strength notation is normally required for sea skimming missile threats that may remove significant areas of above water structure.

3.3 Underwater threats

3.3.1 Shock enhancement should be aimed at providing ruggedness and to verify at a low level, equipment and system operation is maintained and at a higher level, equipment is retained and the hull does not rupture. Notation is currently confined to structure and concentrates on local damage that can be addressed by close attention to quality of construction and by adopting good constructional detail. Shock effects give rise to equipment and system damage. Shock is a different mechanism from whipping, therefore a whipping assessment will not generally be required to the same level of a shock assessment, though it may be necessary to check that the shock threat assessed will not have a significant whipping load. Residual strength assessments may be appropriate for shock threats depending on the extent of local damage.

3.3.2 Whipping is caused by proximity detonation of a charge that excites the main hull girder at a low-order (two node) natural frequency which may cause significant structural damage at a relatively low charge weight. Shock effects therefore may be relatively low order and it will not always be necessary to undertake a shock analysis. In addition a whipping analysis may not be necessary for threats which detonate on contact or for steel ships under 70 m in length. Due to the nature of whipping effects (usually the plastic collapse at a section of the hull), a residual strength calculation is not normally appropriate for a whipping threat because the damage from the direct shock is usually limited.

3.3.3 Residual strength assessments of underwater threats are normally concerned with contact mines or torpedo impacts. These will remove a certain amount of hull structure the effect of which is to be assessed by the residual strength calculation. Shock or whipping threats will only require a residual strength notation where there are significant amounts of local deformation to the hull girder. Significant damage is defined as that which reduces the global strength below the design margins.

3.4 Analysis levels

3.4.1 In addition to levels of capability determined by the threat level specified, there are also different methods of assessment. The method of assessment will depend on three aspects:

- The level of the threat. At higher levels of threat, the requirements of the rules may become uneconomical or impractical and a more in depth analysis is required.
- Applicability of the rule formulations. If the threat level is outside the range of applicability of the rule formulations further analysis will have to be undertaken.

- Acceptance criteria, dependent upon whether the threat is to be assessed against elastic or plastic collapse criteria.

3.4.2 Three methods of assessment are shown in *Figure 1.3.1 Assessment methods 1*. In general the same threat level can be specified in each case however, it is the responsibility of the Owner to specify the correct levels to meet their specific requirements.

(a) The analysis of military loads can most simply be assessed using the elastic model created for rule analysis. This will result in an acceptable but conservative solution.
(b) The next more complex method uses an elasto-plastic or ultimate strength model.
(c) Finally more complicated processes such as 3D dynamic analysis can be used to determine the loading for the elasto-plastic model. Normally this will be carried out for local areas of interest.

3.4.3 Once an ultimate strength model has been created for the appropriate sections along the hull it may be utilised for a variety of military notation calculations, as shown in *Figure 1.3.2 Assessment methods for higher threat levels*.

3.4.4 The damage required for the residual strength calculation can be defined in a variety of ways for a variety of threats, collisions or groundings. Non-military damage is defined in *Vol 1, Pt 6, Ch 4, 4 Residual Strength Assessment, RSA* and military damage by the damage radii in *Vol 1, Pt 4, Ch 2, 7 Residual strength* or specifically from external blast and vulnerability calculations. The results from a vulnerability analysis can be used for input to a variety of military notations and, in general, formal vulnerability assessments will be required for higher threat levels, *see Vol 1, Pt 4, Ch 1, 2.1 General 2.1.4*

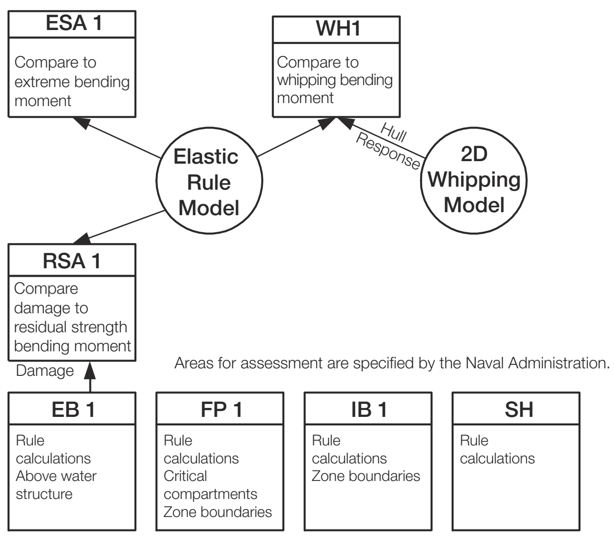


Figure 1.3.1 Assessment methods 1

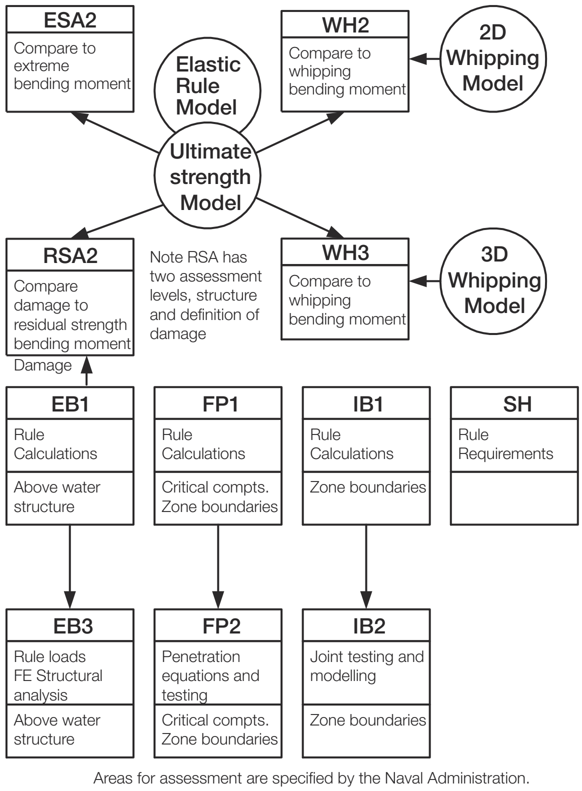


Figure 1.3.2 Assessment methods for higher threat levels

■ *Section 4* Military design guidance

4.1 Radar signature

4.1.1 The Owner is responsible for determining the level of signature control required and agreeing any resultant design to achieve the required levels. There are however, instances where signature levels are not specified but good design practice may be applied. The following is offered as guidance.

4.1.2 All constructional details on the exposed surfaces of the hull, superstructures, masts and equipment above the design waterline should be considered for their radar reflection properties.

4.1.3 The Radar Cross Section (RCS) of the ship will primarily be controlled by shaping. This concentrates the returned energy into a small number of narrow beams, orientated in sacrificial directions or by directing the returned energy at an angle away from the incident energy. The extent of the orientation of the sacrificial directions should be agreed between the Owner and designer.

4.1.4 Appropriate modelling tools and expert judgement should be used for RCS calculation and assessment at various stages of the design iteration. Consideration should also be given to the RCS measurement of equipment.

4.1.5 Flare and tumblehome as defined in *Figure 1.4.1 Radar reflection* are to be used where possible on all otherwise vertical surfaces. The angle used should be greater than 6°. Consideration should be given to using a single or multiple elevation angles, *see Vol 1, Pt 4, Ch 1, 4.1 Radar signature 4.1.3*. This practice also eliminates the dihedral reflector potentially formed between a horizontal and a vertical surface.

4.1.6 Orthogonal corners give rise to high radar returns in the direction of the originating antenna. Creating dihedral or trihedral right angled reflectors should be avoided. This applies equally to disconnected orthogonal corners, where two (or three)

surfaces do not meet but are orthogonal and a clear line of sight exists between them. This can include items such as: boat bays, reception areas, superstructure overhangs, sponsons and equipment mounts.

4.1.7 Corners which would otherwise be orthogonal should be made non-orthogonal by a minimum of 4°, i.e. avoiding an internal angle of between 86° and 94°. Any shaping which uses angles less than 4° could inadvertently be made ineffective by local plate deformation or build tolerances.

4.1.8 Where doors providing access to the deck penetrate sloped structure, it will be desirable for the door itself to be hung vertically on its hinges. To achieve this it is necessary to recess the door into the sloped plate. Where this approach is adopted, the structure of the door recess should be made non-orthogonal by rotating the vertical sides of the recess by a minimum of 4°.

4.1.9 Avoid single curved surfaces (such as cylinders or cones) with diameters greater than 30 mm. Consideration should be given to replace these items by combinations of flat plates (with appropriate orientations), shielding or choice of appropriate material property.

4.1.10 The use of lattice type masts and equipment supports should be avoided.

4.1.11 Consideration should be given to reducing the amount of clutter (microgeometry) by design, hiding it behind bulkheads or shielding (i.e. shutters for when equipment is not in use).

4.1.12 Where the use of homogenous reflective material is impractical for shielding, a mesh of electrical conductive fibres with an appropriate mesh spacing to simulate a reflective surface over the radar frequency range of interest can be used. This can also be applied to windows and non-structural bulkheads. Where a mesh is applied to windows which may be used for navigation purposes consideration should be given to the effects on visibility.

4.1.13 The number of external ladders should be kept to a minimum. Where they are unavoidable, ladder uprights should be rotated to avoid forming dihedral corners with the bulkheads on which they are mounted. As an alternative, external ladders could be constructed from a material translucent to radar.

4.1.14 Consideration should be given to the use of radar absorbent materials either as appliqués or more preferably as an inherent part of the structure i.e. Structural Radar Absorbent Material (SRAM).

4.1.15 Composites are generally semi-transparent to radar and therefore attention should be paid to equipment/ structures placed behind composite structures. Alternatively, consideration can be given to altering the composite properties, applying a metallic backing to the composite or by using SRAM.

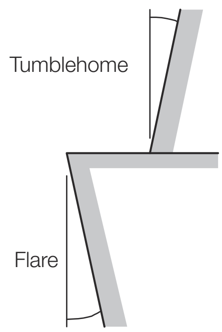


Figure 1.4.1 Radar reflection

4.2 Use of aluminium alloys

4.2.1 Due to the poor performance of aluminium alloys at high temperatures they are generally not to be used for items of main hull structure unless suitable insulation is arranged. Safety critical items such as life boat davits, ladders, fire main supports, emergency escape route bulkheads and floor plates, etc. are not to be constructed of aluminium alloys.

■ Section 5
Military design requirements

5.1 RAS seating and support structure

5.1.1 The strength of seats and supporting structure is to be sufficient to withstand the forces imposed by the equipment for all possible operating conditions and loads from ship motions, *see Vol 1, Pt 5, Ch 3, 5.3 Pressure on internal decks, Pin*. Design calculations are to be submitted.

5.1.2 The seating and supporting structure is to be tested in accordance with a specified standard, *see also Vol 3, Pt 1, Ch 5, 3.1 General 3.1.4*. Care is to be taken to ensure that the test arrangements represent the actual magnitude and direction of loads, and that the loading is applied to all relevant parts of the supporting structure rather than local items only.

5.1.3 Guidance on the loads and requirements for replenishment at sea operations are given in *Vol 1, Pt 4, Ch 2, 9.2 Replenishment at sea loads*

5.1.4 A sufficient deck area clear of projections and equipment suitably strengthened for impact loading is to be provided for the landing of stores and equipment.

5.1.5 RAS equipment is to be designed in accordance with a specified standard, *see also Vol 3, Pt 1, Ch 5, 3.1 General 3.1.4*.

5.2 Vehicle and equipment holding down arrangements

5.2.1 The strength and stiffness of the holding down arrangements and the supporting structure under is to be sufficient to withstand the forces imposed by the vehicle(s) and or equipment for all possible operating conditions and loads from ship motions, *see Vol 1, Pt 5, Ch 3, 5.3 Pressure on internal decks, Pin* The design calculations are to be submitted.

5.3 Masts and externally mounted sensors or equipment

5.3.1 Masts are to be of adequate strength and stiffness for the equipment they support. The design calculations are to be submitted.

5.3.2 Plated mast structure is to be treated as superstructure and the structural requirements for superstructure as defined in *Table 3.3.9 Superstructure plating* and *Table 3.3.10 Superstructure framing* in Pt 6, Ch 3 for NS1 type vessels and *Vol 1, Pt 6, Ch 3, 4.8 Superstructures, deckhouses and bulwarks 4.8.4* and *Vol 1, Pt 6, Ch 3, 4.8 Superstructures, deckhouses and bulwarks 4.8.5* for NS2 and NS3 type vessels are to be applied. Minimum requirements are given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements* and *Vol 1, Pt 6, Ch 2, 2.9 Proportions of stiffener sections*.

5.3.3 Pole mast structure is to be designed to be within the allowable stress limits defined in *Vol 1, Pt 6, Ch 3, 16 Masts*.

5.3.4 The excitation of the mast by ship motions, machinery, propellers and equipment is to be specially considered and the designers calculations are to be submitted. Where possible the designer should avoid mast natural frequencies within ±20 per cent of significant global mast excitation frequencies. Where this is not possible the vibration amplitudes should be calculated to confirm they are within acceptable limits for the mast structure and equipment. In general, ship motions can be estimated from *Vol 1, Pt 5, Ch 3, 2 Motion response*. *See also Vol 1, Pt 6, Ch 2, 4 Vibration control*. It is recommended that the frequency of the first mode of vibration of a pole mast be not less than 3,0 Hz to prevent potential excitation from the first vertical hull girder vibration mode in the range 1-2,5 Hz. The frequency of the first mode of vibration of a pole mast should be a minimum of 1 Hz above the first vertical hull girder mode.

5.3.5 Structure supporting radar or equipment critical to the operation of ship systems is to be of adequate stiffness to maintain the alignment of the equipment within the tolerance agreed with the manufacturer.

5.3.6 The mast should be designed and sited such that it produces minimum interference with the ships sensors and equipment.

5.3.7 Suitable permanent access arrangements are to be provided inside and on the exterior of the mast for maintenance of the structure and equipment. Provision is to be made for the drainage of water from all parts of the mast, both internal and external. Where applicable, protective coatings are to be applied in accordance with the requirements of *Vol 1, Pt 6, Ch 6, 2.6 Paints and coatings*. For corrosion margins, *see Vol 1, Pt 6, Ch 6, 2.10 Corrosion margin*.

5.3.8 Mast support arrangements are to be of suitable strength and stiffness and fully integrated into the hull or superstructure. The design calculations and arrangements are to be submitted.

5.3.9 For equipment distributed along the length of the ship, consideration is to be given to the global stiffness of the ships' hull girder in relation to the alignment tolerances required for the equipment (increasing hull stiffness is not normally an efficient option).

5.3.10 High powered transmitting equipment where fitted is to be considered for the effects of electromagnetic influence on adjacent equipment and manned spaces.

5.4 Towed arrays, towed bodies and towing points

5.4.1 The support structure of towed systems is to be suitably integrated into the main hull structure. Any additional primary stiffening is to be extended for at least three frame spaces forward and aft of the equipment.

5.4.2 The towing point and associated equipment is to be located over a primary longitudinal girder and preferably supported by a transverse web frame. The designers calculations are to be submitted for the supporting structure using the 1,5 times the maximum breaking load of the cable.

5.4.3 Towed array handling equipment is to be designed in accordance with a specified standard. The seating of array handling equipment is to be adequately supported.

5.5 Crane support arrangements

5.5.1 Crane pedestals are to be efficiently supported and in general, are to be carried through the deck and satisfactorily scarfed into the surrounding structure. Alternatively, crane pedestals may comprise a foundation, in which case the foundation and its supporting structure are to be of substantial construction. Proposals for other support arrangements will be specially considered.

5.5.2 The scantlings of masts and derrick posts, intended to support derrick booms, conveyor arms and similar loads, and of crane pedestals are to be designed in accordance with a specified standard. When submitting plans for the proposed foundation, the design calculations are to be included.

5.5.3 Deck plating and underdeck structure are to be reinforced under masts, derrick posts or crane pedestals, and where the deck is penetrated the deck plating is to be suitably increased.

5.5.4 The pedestal or proposed arrangement is to be designed with respect to the worst possible combinations of loads resulting from the crane self weight, live load, wind and crane accelerations together with those resulting from the ship's heel and trim. The designers calculations are to be submitted.

5.5.5 Stowage arrangements are to be taken into account when calculating the loads applied to the pedestal.

5.5.6 Insert plates are to be incorporated in the deck plating in way of crane foundations. The thickness of the insert plates is to be as required by the designer's calculations but is in no case is to be taken as less than 1,5 times the thickness of the adjacent attached plating.

5.5.7 All inserts are to have well radiused corners and be suitably edge prepared prior to welding. All welding in way is to be double continuous and full penetration where necessary. Tapers are to be not less than three to one.

■ *Section 6*
Magazine design and construction requirements

6.1 General

6.1.1 The design, construction and maintenance of magazines are to be in accordance with the specified magazine safety standard, *see Vol 1, Pt 1, Ch 2, 1.1 Framework of Classification 1.1.13*. All Regulations, recommendations and requirements are to be confirmed to have been applied.

6.1.2 Where standards have not been specified the following requirements apply. A Risk Assessment, in accordance with *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*, may be used to justify alternative arrangements. This is to be approved by the Owner and Naval Administration. All recommendations and requirements are to be demonstrated to have been applied.

6.1.3 A statement of magazine requirements is to be defined and is to include:

(a) Armaments requirement; listing the expected munitions and materiel to be carried in magazines. Identifying the items which can or are to be co-located and those which must be stored separately or separated. Any special requirements for the storage of particular items are also to be listed including:
   (i) environmental conditions; and
   (ii) conductive deck coating requirements.
(b) Construction materials requirement; describing the permissible materials or required alternatives for magazine structures and munition stowages.
(c) Magazine Labelling requirement; describing the required labels and their locations.
(d) Fluid Systems requirement; describing the operating fluids and operating pressures of all fluid systems within the magazine boundaries.
(e) Munition handling requirement; describing the equipment and space requirements to enable the munitions to be safely handled, maintained and stowed.

6.1.4 Munition securing and handling equipment is to be in accordance with requirements of the Armaments Requirement or, with special consideration, LR's LAME Code. Explosive stores are to be classified and stowed in accordance with the armament requirement, *see Vol 1, Pt 4, Ch 1, 6.1 General 6.1.3*.

6.1.5 Ready use magazines are not to be used for the permanent stowage of munitions. They are to comply with the requirements of this Section for the appropriate magazine type.

6.2 Definitions

6.2.1 Munitions are a complete device (e.g. missile, shell, mine, demolitions store, etc. charged with explosives, propellant, pyrotechnics, or initiating composition), for use in conjunction with offensive, defensive, training, or non-operational purposes, including those parts of the weapon systems containing explosives.

6.2.2 Explosives are all weapons, missiles or stores containing substances especially designed to produce an explosive, propulsive, incendiary or pyrotechnic effect for use in conjunction with offensive, defensive, training, or non-operational purposes.

6.2.3 Integral magazines are those which are bounded by the elements of the main hull structure. They are specifically designed and constructed for the safe permanent stowage of the main outfit of designated munitions defined in the armaments requirement, *see Vol 1, Pt 4, Ch 1, 6.1 General 6.1.3*.

6.2.4 Independent magazines are those that are non integral, portable magazines greater than 3 m^3 and the requirements for integral magazines are to be applied where applicable.

6.2.5 Small magazines are compartments opening off the upper deck which are of shape and size which does not permit walk-in and where the contents are handled from outside. Small magazines are to be specifically designed and constructed for the safe permanent or ready use stowage of munitions defined in the armaments requirement, *see Vol 1, Pt 4, Ch 1, 6.1 General 6.1.3*.

6.2.6 Magazine lockers are magazines less than or equal to 3 m^3, designed and constructed for the safe stowage of explosive stores for which in built magazine facilities have not been provided. They are to be free standing and surrounded by an air gap such that they do not have an adjacent compartment.

6.2.7 Magazine boxes are non-integral, portable magazines with a capacity less than or equal to 3 m^3 and capable of being jettisoned overboard.

6.2.8 Pyrotechnics lockers are to comply with the requirements for small magazines, magazine lockers or boxes as appropriate.

6.2.9 Class A fire divisions are those divisions formed by bulkheads and decks which comply with the requirements of IMO resolution MSC 61 (67) *Fire test procedures code*, Annex 1,*Part 3 - Test for “A”, “B” and “F” Class Divisions*.

6.3 Arrangement of magazines

6.3.1 Integral magazines and small magazines containing munitions or propellant are not to be sited adjacent to high fire risk and other compartments of high fire risk listed below:

(a) Machinery spaces of category A.
(b) Galleys.
(c) Switch boards or electrical control rooms.
(d) Tanks containing liquids with a flashpoint lower than 60ºC or with a temperature above 32ºC.

(e) Compartments containing liquid oxygen.
(f) Fuel, petrol, oil or lubricant pump spaces.
(g) Accommodation spaces.
(h) Control Spaces.

6.3.2 Access is not permitted from any of the spaces defined in *Vol 1, Pt 4, Ch 1, 6.3 Arrangement of magazines 6.3.1*, to the magazine.

6.3.3 For ships where the above arrangement is completely impracticable the magazine is to be separated from the high risk space by a minimum 600 mm wide cofferdam and constructed of steel or an A-30 fire division. Cofferdams are to comply with the requirements of *Vol 1, Pt 3, Ch 2, 4.9 Cofferdams*, are to be ventilated and are not to be designed or used for stowage purposes.

6.3.4 No gasoline or pressurised bottle stowage is to be within a 6 m radius of any magazine or locker.

6.3.5 Integral magazines and small magazines containing munitions may be sited adjacent to the following compartments of moderate fire risk provided that they are separated by an A-30 fire division:

(a) Auxiliary machinery spaces including pump rooms air condition plant spaces, refrigeration compartment spaces and hydraulic compartments not containing flammable hydraulic fluids.
(b) Service spaces, including laundries and workshops.
(c) Uptakes and downtakes.
(d) Hangars, docks and vehicle decks.
(e) Paint, flammable, battery and acid stores.
(f) Tanks or compartments containing independent tanks, of liquids other than sea or fresh water.

6.3.6 Magazine lockers are to be sited in a safe location on a weather deck, surrounded by an air gap of at least 300 mm on all sides and where applicable protected from direct sunlight by fitting solar cladding over top and sides with an air gap of at least 25 mm.

6.3.7 Within magazines arrangements are to be such to ensure that all munitions, including those in transit packaging, are safely stowed and suitably restrained in their stowage for predicted motions and environmental conditions as identified in the armaments requirement. Separate stowage is to be provided for each type of explosive except where specified by the armaments requirement, *see Vol 1, Pt 4, Ch 1, 6.1 General 6.1.3*.

6.3.8 Magazines are to provide suitable electromagnetic screening and earthing arrangements for munitions as identified in the armaments requirement, *see Vol 1, Pt 4, Ch 1, 6.1 General 6.1.3*.

6.3.9 Magazine boxes are to be sited on a weather deck with an air gap of at least 300 mm between the box and the deck or surrounding deck houses. They are to be located in a position suitable for jettisoning of the contents and capable of remote release.

6.3.10 Detonators are to be stowed separately from other explosives in dedicated lockers or storerooms; such spaces are to be treated as designated danger areas. Co-location may be allowed as identified in the armaments requirement, *see Vol 1, Pt 4, Ch 1, 6.1 General 6.1.3*.

6.4 Structure

6.4.1 Integral magazines are to be of permanent watertight or gastight construction (*see Vol 1, Pt 3, Ch 2, 1.3 Watertight and weathertight integrity* and *Vol 1, Pt 3, Ch 2, 7.7 Unusual designs*) and formed by permanent A-15 class divisions. A-0 class divisions may be allowed if spaces adjacent to the magazine do not contain flammable products.

6.4.2 Independent magazines are to be of weathertight metal construction, *see Vol 1, Pt 3, Ch 2, 1.3 Watertight and weathertight integrity*. The interior is to be insulated with a non-combustible insulation providing an A-15 standard.

6.4.3 Magazine lockers and magazine boxes are to be constructed of steel. Other material may be accepted as identified in the construction materials requirement, *see Vol 1, Pt 4, Ch 1, 6.1 General 6.1.3*.

6.4.4 The scantlings of integral magazine boundaries are to be determined from *Table 3.3.15 Magazine bulkhead and deck scantlings* in Pt 6, Ch 3 for NS1 ships and the general plating and stiffening equations in *Vol 1, Pt 5, Ch 3, 5.8 Design pressures for watertight and deep tank bulkheads and boundaries* for other ships. The design pressure, P_{mag}, is to be derived as shown in *Vol 1, Pt 5, Ch 3, 5.11 Design pressure for magazine decks and bulkheads*.

6.4.5 If venting from the magazine space is via a vent trunk, the required scantlings for the vent trunk structure are to be calculated as for magazine boundary requirements.

6.4.6 Vent plate structure and fittings are to be designed to meet the appropriate deck or bulkhead pressure requirements according to location.

6.5 Environmental conditions and ventilation

6.5.1 The temperature of the magazine is to be maintained at the environmental conditions required by the armaments requirement, *see Vol 1, Pt 4, Ch 1, 6.1 General 6.1.3*. Generally munitions are to be stored at temperatures greater than 7°C and less than 35°C with a relative humidity between 30 and 70 per cent. Munitions with propellant are to be maintained below 32°C.

6.5.2 The air conditioning may be recirculatory if confined to the ventilation of magazines only. If the magazine is to be ventilated with other compartments then the magazine is to vent to atmosphere. High fire risk and high value compartments should not share ventilation with magazines.

6.5.3 Where a magazine or magazine complex may require to be manned, fresh air make up, via the Air Filtration Unit is to be provided.

6.5.4 Emergency life support apparatus is to be sited in magazines where personnel are required to be permanently working.

6.5.5 Ventilation trunking is to be of an equivalent fire integrity standard as the magazine.

6.5.6 Air conditioning and ventilation systems are to be designed to maintain watertight integrity and flash.

6.6 Detail arrangements

6.6.1 Clear labelling of all magazine openings and equipment is to be maintained in accordance with the magazine labelling requirement, *see Vol 1, Pt 4, Ch 1, 6.1 General 6.1.3* The following requirements are to be applied as a minimum:

(a) Integral, small and independent magazines:
- (i) the space is a magazine.
- (ii) open lights and flame are to be kept away.
- (iii) the magazine door is to be kept shut.
- (iv) sources of ignition such as matches,lighters and pocket torches are to be removed prior to entry.
- (v) not to lift with contents (in the case of independent magazines).
- (vi) magazine otherside markings in adjacent compartments.

(b) Magazine lockers and boxes:
- (i) the container is a magazine locker or box.
- (ii) open lights and flame are to be kept away.
- (iii) the box is to be kept shut.
- (iv) not to lift with contents.

6.6.2 Magazines are to be insulated with non-combustible material as necessary to prevent the condensation of moisture.

6.7 Openings

6.7.1 Openings in the magazine and lockers such as doors, hatches and escape scuttles are to be of equivalent strength and fire integrity as the surrounding structure.

6.7.2 Accesses to magazines are to be fitted with suitable security arrangements to prevent unauthorised access. Openings are to be capable of being secured from the inside and fitted with external locks. Emergency escapes are to be opened from the inside only.

6.7.3 Locking arrangements on all magazines and lockers are to be designed to prevent the possibility of entry by removing the hinge pins.

6.8 Piping, cabling and electrical systems

6.8.1 In order to eliminate potential sources of ignition in a magazine in which flammable mixtures are liable to collect, hazardous areas for magazines are to be identified and electrical equipment within the magazine is to be selected and installed in accordance with the requirements of *Vol 2, Pt 9, Ch 5, 4 Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts*.

6.8.2 Lighting is to be operated from outside the space. Indication is to be provided at the switch location when circuits are energised.

6.8.3 All apparatus fitted in magazines is to be capable of being isolated on all poles from any source of electrical energy. The preferred method of isolation is by means of a multipole switch. Services that operate on low power at low voltage and are required to operate continuously do not require local isolation. Fire and flood detection and internal communications systems are included amongst such services.

6.8.4 Only services which are required for equipment in the magazine are to penetrate boundaries of the magazine.

6.8.5 Air and hydraulic systems used within magazines are to be low pressure systems only. Non-flammable hydraulic fluid is to be used.

6.8.6 Electrically controlled handling machinery may be fitted in magazines provided that continuous earth monitoring is provided in the control circuits of the machinery.

6.8.7 Equipment and light fixtures installed in magazines which may be subjected to mechanical damage are to be equipped with suitable protection against such damage. All protective metal guards for apparatus and cabling as well as the apparatus itself must be effectively earthed. Where required, conduit is to be electrically continuous and bonded to earth to form an effective shield.

6.9 Fire protection

6.9.1 Integral and small magazines are to be fitted with a spray system capable of rapid reaction, with manual activation and a suitable permanent drainage system.

6.9.2 The spray system is to be capable of delivering 30 litres/m^2/min. Large compartments may be fitted with independent spray systems covering separate areas.

6.9.3 Spray heads are to be arranged within magazines so that all stowages and boundaries are covered when sprayed.

6.9.4 Spray systems for integral magazines are to be fed from two separate sections of the ship's water supply.

6.9.5 Magazine lockers and boxes are to be fitted with flood and drainage systems. The flood system is to be operated by a manual control adjacent to the locker but at least 5 m away or 3 m if suitably screened and fed from a pressurised water supply.

6.9.6 Compartments other than tanks or void spaces adjacent to magazines are to be fitted with smoke or fire detectors.

6.9.7 Locking arrangements are to be fitted to all spray, flooding, drain valves and cocks with the exception of spray control valves when housed in a lockable cabinet.

6.9.8 Magazines are to be provided with fire extinguishers commensurate with risk classification, size and type of vessel. Generally one extinguisher should be fitted on the inside and one on the out side of the magazine.

6.9.9 Designated danger areas (DDA) where munitions are handled such as weapon lifts, transfer passages, weapon preparation areas, hangars, flight decks, docks and RAS points are to be fitted with similar fire protection systems to the magazine, commensurate with the risk classification and type of vessel. LR may allow system requirements to be reduced to the provision of sufficient hose points based on the risk classification.

6.9.10 Magazines are to be coated with fire resistant paint and the deck covering is to be non spark and non slip. Any requirements for a conductive deck area and personnel will be identified in the armaments requirement, *see Vol 1, Pt 4, Ch 1, 6.1 General 6.1.3*. Where there is a conducting deck requirement an anti static precaution notice is to be displayed.

6.10 Testing

6.10.1 Magazines are to be tested in accordance with the gas tight requirements of *Vol 1, Pt 6, Ch 6, 6.8 Gastight testing*.

■ *Section 7*
Design guidance for nuclear, biological and chemical defence

7.1 General

7.1.1 The arrangements of hull structure for chemical, biological, radiological and nuclear defence (CBRN) are to generally be in accordance with the requirements of this section. The final design and arrangements are to be in accordance with a specified standard. Where specifically requested, LR can undertake the inspection and certification of CBRN arrangements or gastight integrity, *see Vol 1, Pt 6, Ch 6, 6.8 Gastight testing*.

7.1.2 The subdivision of the ship for CBRN defence is achieved by the provision of zones which minimise the consequences of an attack. The zone boundaries provide protective barriers to resist the spread of primary and secondary weapon effects.

7.1.3 The number and location of zone boundaries and distribution of systems within those zones is best determined by carrying out a vulnerability analysis as detailed in *Vol 1, Pt 4, Ch 1, 2 Survivability*.

7.1.4 The effect of zones on, and requirements for damage control should also be considered. This is best assessed by testing the zone arrangement with a series of 'what if' damage scenarios. A good zone arrangement will aid damage control.

7.1.5 An effective CBRN defence is to comprise of three distinct phases:

- Monitoring and detection by the provision of systems to detect the presence of and to identify the threat both outside the ship and within the zones.
- Protection of the ship and crew, using a pressurised citadel and zones with gas-tight boundaries and airlocks. Protection is also achieved with the filtration of air drawn into the ship and enclosing machinery intakes and exhausts.
- Decontamination of spaces within the ship is achieved using a suitable ventilation and filtration system. Decontamination of the ship itself is largely achieved using pre-wetting systems. For the crew and equipment, cleansing stations can be used.

7.2 Definitions

7.2.1 A citadel is the gastight envelope of the hull and superstructure. It consists of a group of interconnecting compartments enclosed by a gas-tight boundary with the independent systems necessary to provide a toxic free area free from any CBRN hazard. Large ships may have subcitadels or more than one citadel.

7.2.2 A zone is a smaller group of compartments within the citadel with some or all of the independent systems necessary to provide a toxic free area that is free from any CBRN hazard.

7.2.3 An airlock is a compartment with two doors between the toxic free area and the source of the CBRN hazard or cleansing station. Airlocks are normally purged with clean air to allow personnel to pass from one area to another without contaminants entering the toxic free area.

7.2.4 A cleansing station is a group of compartments suitably arranged and equipped whereby CBRN decontamination of personnel and materials can take place.

7.2.5 Individual protective equipment is the personal clothing and equipment required to protect an individual from CBRN hazard. It normally consists of a protective suit and respirator.

7.3 NS1 and NS2 ship requirements

7.3.1 The requirements of this Section deal only with the hull structure and mainly involve the arrangement of major divisions within the hull. Provision is to be made within the layout and design of the ship for the compartments required for CBRN defence. It is recommended that they are considered from a very early stage in the design.

7.3.2 Unless specified otherwise, the citadel's length is to be divided into zones. It is recommended that the zone boundaries coincide with main transverse watertight bulkheads and extend from the keel to the highest superstructure deck.

7.3.3 A suitable pressure above atmospheric is to be maintained inside the citadel and zones. Zones with a higher risk of contamination are to be maintained at a lower pressure than the adjacent zones but higher than atmospheric. For example those containing machinery spaces with ventilation to atmosphere open during CBRN conditions.

7.3.4 For NS1 ships at least three cleansing stations are to be provided in separate zones. For NS2 ships at least two cleansing stations are to be provided in separate zones. They are to be located so that safe and direct entry is possible from the weather deck. One cleansing station is to be located close to the medical complex with access for stretcher borne casualties.

7.4 NS3 ship requirements

7.4.1 The requirements of this Section deal only with the hull structure and mainly involve the arrangement of major divisions within the hull. It is recommended that they are considered from a very early stage in the design.

7.4.2 For NS3 ships it may be impractical to provide zones and a citadel. In this case CBRN protection is to be provided by either individual protective equipment or sanctuaries.

7.4.3 Sanctuaries may be integral or temporary compartments on board the ship and are to be provided with an airlock, cleansing station and ventilation systems similar to that of a zone.

7.4.4 If individual protective equipment is provided arrangements are to be made to ensure that operation of the ship is possible such that it can reach a suitable place of refuge. For example, crew provisions, equipment and compartment accesses are to be suitable for persons wearing individual protective equipment.

7.5 Zones

7.5.1 The boundaries of zones are to be gastight and are to be tested in accordance with *Vol 1, Pt 6, Ch 6, 6.8 Gastight testing*. Ventilation and trunking is not to pass through zone boundaries.

7.5.2 Each zone is generally to be provided with a total air conditioning system. All air entering the citadel is to pass through CBRN filters. These filters may be bypassed when the ship is not in a threat situation.

7.5.3 Consideration is to be given to the provision of independent services in each zone for the following systems:

(a) Electrical power generation and distribution.
(b) Chilled water cooling.
(c) Fire pumps, piping and hydrants (including pre-wetting).
(d) Bilge pumps, piping and discharge.
(e) Internal communications.
(f) Machinery or damage control surveillance or control.
(g) Compressed air.
(h) Emergency crew support.
(i) Smoke clearance arrangements.
(j) Air start arrangements in the appropriate zones.

7.5.4 At least two airlocks to the weather decks are to be provided in each zone. Access between zones are to be fitted with airlocks. Consideration is to be given to providing gas-tight connections adjacent to this access for the provision of the services listed in *Vol 1, Pt 4, Ch 1, 7.5 Zones 7.5.3*.

7.5.5 Consideration should be given to the use of materials that do not emit toxic fumes.

7.6 CBRN hardening

7.6.1 In determining the layout and design of the ship consideration should be given to the hardening of the ship to improve its capability in an CBRN environment.

7.6.2 All external compartments and equipment not included in the citadel should be sealed or designed such that residual contaminants cannot be trapped.

7.6.3 All access for operation and maintenance of equipment should be designed for personnel wearing individual protective equipment.

7.6.4 Shelters are to be provided deep within the ship for the temporary protection from radiation of the crew during nuclear attack.

7.6.5 Command and control centres should ideally be sited such that they are afforded the maximum protection against radiation from nuclear attack. All relevant Mobility and Ship Type equipment should be designed to resist incident nuclear radiation (INR) and nuclear electromagnetic pulse (NEMP).

7.7 Structural requirements

7.7.1 The scantlings of all gas-tight zone, citadel and airlock boundaries are to be capable of withstanding two times the maximum differential pressure that can occur in service and the scantlings are to be calculated in accordance with the relevant Sections of *Vol 1, Pt 6, Ch 3 Scantling Determination*. Gas-tight boundaries are to be tested in accordance with *Vol 1, Pt 6, Ch 6, 6.8 Gastight testing*.

7.7.2 All openings in gastight boundaries are to be fitted with gas-tight closing appliances and tested in accordance with *Vol 1, Pt 6, Ch 6, 6.8 Gastight testing* and are to be of equivalent strength to the structure in which they are placed.

7.7.3 Watertight and weathertight closing appliances may be considered gas-tight if a pressure greater than atmospheric is, and can be maintained inside the zone, citadel or airlock.

Section 8
Design guidance for the reduction of radiated noise underwater due to sea-inlets or other openings

8.1 General

8.1.1 The number of underwater openings should be kept to a minimum.

8.1.2 To aid in the reduction of underwater radiated noise, sea tubes and/or boxes are to be provided for each sea-water hull inlet or outlet. Where a number of openings are adjacent, consideration should be given to fitting a common plenum chamber with a single opening in the outer bottom. Care must be taken to avoid resonance of the chamber.

8.1.3 The outside of all underwater openings is to be flush with the surrounding hull plating. Particular care is to be taken to provide smooth surface on the inside of all sea tubes and discharges.

8.1.4 For sea openings required to be blanked, a smooth mating face surrounding the sea tube on to which the mating flange of the blank can sit is to be provided.

8.1.5 Adequate protective coating and cathodic protection should be considered at the interface of the valve and sea tube.

8.1.6 No underwater opening, at a level lower than the deep design draught, is to be fitted within 6 m of the aftermost part of the aft sonar dome.

8.1.7 Wherever possible, gratings or anti-sabotage bars fitted to underwater openings are to be arranged across and aligned with the flow of the water past the ship so as to minimise turbulence. They should be deep in section and have well radiused edges.

■ *Section 1* General requirements

1.1 General

1.1.1 This Chapter contains design requirements that have to be complied with as part of ✠ **100A1** classification, ship type or a special notation such as **IB**.

1.1.2 Where significant regions of the hull structure are rendered ineffective by the threat under consideration, a residual strength calculation is to be carried out to verify the capability of the remaining structure.

1.1.3 For structure designed in accordance with the appropriate Sections of this chapter the following notations will be assigned. The level of threat and notation will remain confidential to the Owner and Lloyd's Register (hereinafter referred to as 'LR') unless requested otherwise.

- **EB** for external blast assessment.
- **IB** for internal blast assessment.
- **FP** for fragmentation protection.
- **SP** for small arms protection.
- **SH** for assessment against underwater explosion (shock).
- **WH** for whipping assessment.
- **RSA** for a residual strength assessment, *see Vol 1, Pt 6, Ch 4, 4 Residual Strength Assessment, RSA*.

■ *Section 2* External blast

2.1 General

2.1.1 Structures and their response to air blast loadings, can be considered to fall into two categories:

- Diffraction-type structures.
- Drag-type structures.

2.1.2 In a nuclear type explosion, the diffraction-type structures would be affected mainly by diffraction loading and the drag-type structures by drag loading.

2.1.3 Large flat sided structures, with few openings, will respond mainly to diffraction loading because it will take an appreciable time for the blast wave to engulf the structure and the pressure differential between front and rear exists during the whole of this period. A diffraction-type structure is primarily sensitive to the peak over-pressure in the shock wave to which it is exposed.

2.1.4 If structures are small, or have numerous openings, the pressures on different areas of the structure are quickly equalised; the diffraction forces operate only for a very short time. The response of this type of structure is then mainly due to the dynamic pressure (or drag forces) of the blast wind. This is typical of masts and funnels. The drag loading on the structure is determined not only by the dynamic pressure but also by the shape of the structure. The drag coefficient is less for rounded or streamlined structures than for irregular or sharp edged structures.

2.1.5 The relative importance of each type of loading in causing damage will depend upon the type of structure as well as the characteristics of the blast wave.

2.2 Threat level determination

2.2.1 Ships complying with the requirements of this Section will be eligible for the notation **EB1, EB2, EB3** or **EB4** as defined in *Vol 1, Pt 4, Ch 2, 2.3 Notation assessment levels and methodology*.

2.2.2 External blast loading can come from a variety of threats the two main ones are far field from nuclear or fuel air type threats and near field from detonation by close in weapon systems. This part of the Rules is concerned only with the far field explosions.

2.2.3 The actual threat level used in the calculation of performance and the areas of the ship to be protected by this design method are to be specified by the Owner and will remain confidential to LR.

2.3 Notation assessment levels and methodology

2.3.1 Design to withstand increasing levels of blast pressure needs to employ increasing sophistication and complexity of analysis method if the structure is to be kept lightweight.

2.3.2 An **EB1** assessment method may utilise the simple design methodology suggested in *Vol 1, Pt 4, Ch 2, 2.8 Conventional explosive pressure loads* for structural assessment. The design criteria should ensure that the structure behaves in an elastic perfectly plastic manner with small displacements when subjected to the proposed blast level.

2.3.3 An **EB2** assessment method may utilise an extension of simple design methodology suggested in *Vol 1, Pt 4, Ch 2, 2.8 Conventional explosive pressure loads* to look at the elasto-plastic behaviour for the structural assessment. The structure is to be designed such that maximum displacements experienced by all structure does not compromise the structural integrity, water or gas-tight integrity or functioning of critical items of equipment required for operation of the ship and systems that is attached or adjacent to the structure.

2.3.4 An **EB3** assessment method should employ a failure criterion based on an elasto-plastic methodology which considers the following structural responses:

- Local response of the plating, here the plating can be represented as a 2D plate strip and a large displacement, elasto-plastic dynamic response analysis carried out using a beam-column approach.
- Local bending response of stiffened panels, the preferred model will be to evaluate the non-linear dynamic response of a single stiffener with an attached strip of plating modelled as a beam-column with the appropriate boundary conditions under blast pressure.
- A lumped parameter model can be employed to look at ‘overall sidesway’ response of a ships superstructure.

The structure is to be designed such that maximum displacements experienced by all structure does not compromise the structural integrity, water or gas-tight integrity or functioning of critical items of equipment required for operation of the ship and systems that are attached or adjacent to the structure.

2.3.5 An **EB4** assessment method should employ a full non-linear analysis using finite element methods to predict the structural response. Using this methodology it is assumed that the ship must survive, this implies the need to retain primary hull structural integrity, water and gas-tight integrity or functioning of critical items of equipment required for operation of the ship and systems that is attached or adjacent to the structure.

2.3.6 For **EB3** and **EB4** notations, the assumptions made for initial deformations are to be submitted. Where these differ for normal ship building practice, the details are to be recorded on the approved plan.

2.4 Definitions

2.4.1 Atmospheric pressure P_o is to be taken as 101,3 kN/m^2.

2.4.2 The dimensions of superstructure blocks are given in *Figure 2.2.1 Superstructure definitions*.

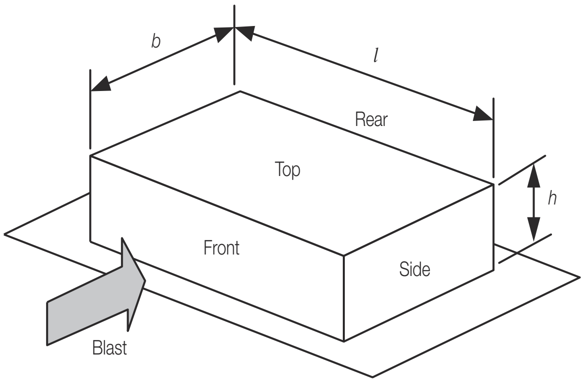


Figure 2.2.1 Superstructure definitions

2.5 Blast pressure loads

2.5.1 For explosions of different magnitude, the range at which the peak blast incident and dynamic pressures occur can be scaled using the following equation.

$D_\mathrm{i} = D_\mathrm{n}\left(\frac{1000}{W}\right)^{1/3}$ where

D_i = incident distance

D_n = the distance at which the pressure occurs, in metres

W = the equivalent weight of TNT for the explosive, in kg.

2.5.2 Similarly for weapons of a different magnitude, the duration t_{p+} of a blast can be scaled using the scaling equation

$t_\mathrm{i} = t_\mathrm{n}\left(\frac{1000}{W}\right)^{1/3}$ where

t_i = incident duration

t_n = duration the pressure occurs, in seconds

W = the equivalent weight of TNT for the explosive, in kg.

2.5.3 When a pressure shock front strikes a solid surface placed normal to the direction of shock travel there is an instantaneous rise in pressure above that of the shock front itself. The total pressure referred to as the reflected pressure is given by:

$$P_\mathrm{r} = 2P_\mathrm{i}\left(7P_\mathrm{o} + 4P_\mathrm{i}\right)/\left(7P_\mathrm{o} + P_\mathrm{i}\right)\ \mathrm{kN/m^2}$$

when $P_i << P_o$ (small charge at large stand off) P_r may be taken as 2P_i similarly when $P_i >> P_o$ (large charge at short range) P_r may be taken as 8P_i

where P_i = peak blast incident over-pressure in kN/m^2 from *Figure 2.2.2 Blast parameters for TNT and nuclear explosions*

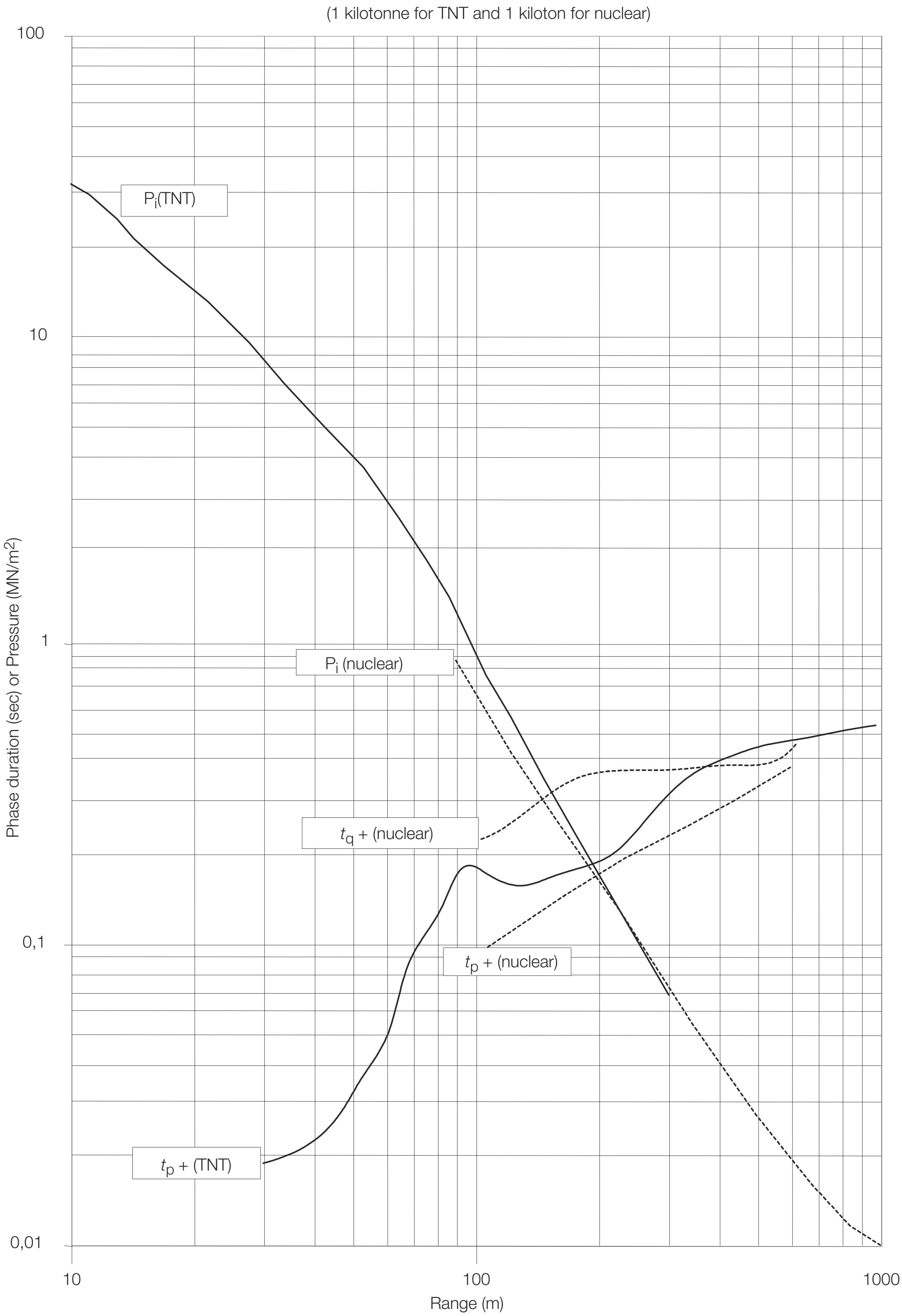


Figure 2.2.2 Blast parameters for TNT and nuclear explosions

2.5.4 The reflected pressure, P_r can be assumed to diminish linearly until it reaches the stagnation pressure P_s at time t_s where

$$t_s = 3d/U\ seconds$$

where

d = is the lesser of h or ⋉/2 in metres, *see Figure 2.2.1 Superstructure definitions*

U = shock front velocity in m/s

= $U_o\sqrt{1 + 6P_i/7P_o}$

U_o = speed of sound in air in m/s

= 332+0,6T_o

T_o = ambient air temperature in °C.

2.5.5 The passage of the blast is immediately followed by a transient 'blast wind' that exerts a supplementary dynamic pressure which is given by:

$$q_i = 2,5\left(P^2{}_i/\left(7P_o + P_i\right)\right)\ \mathrm{kN/m^2}$$

where

P_i = peak blast incident over-pressure in kN/m^2 from *Figure 2.2.2 Blast parameters for TNT and nuclear explosions*

The duration of the dynamic pressure, t_{q+}, can be determined from *Figure 2.2.2 Blast parameters for TNT and nuclear explosions*.

2.5.6 The stagnation pressure, P_s, is determined for the front of the superstructure block by

$$P_s = P_i + C_D q_i\ \mathrm{kN/m^2}$$

and for the top, sides and rear by

$$P_s = P_i - C_D q_i\ \mathrm{kN/m^2}$$

where

P_i = peak incident pressure from *Figure 2.2.2 Blast parameters for TNT and nuclear explosions*

q_i = the dynamic pressure from *Vol 1, Pt 4, Ch 2, 2.5 Blast pressure loads 2.5.5*

C_D = the drag coefficient of the structure from *Table 2.2.1 Drag coefficients*.

Table 2.2.1 Drag coefficients

Structure	Drag coefficient, C_D
Ship sides	+1,0
Front face	+1,0
Top and sides	
0–170 kN/m^2	+0,4
170–340 kN/m^2	+0,3
340–930 kN/m^2	+0,2
Masts and funnels	+0,75

2.5.7 For the top and sides of the superstructure the peak pressure will occur at time t_t which is given by:

$t_t = b/U\ seconds$

where

b = superstructure breadth in m, *see Figure 2.2.1 Superstructure definitions*

U = shock front velocity in m/s, *see Vol 1, Pt 4, Ch 2, 2.5 Blast pressure loads 2.5.4*.

2.5.8 For the rear of the superstructure the peak pressure will occur at time t_r which is given by:

$t_t = b/U + 4d/U\ seconds$

where

d = is the lesser of h or ⋉/2, in metres, *see Figure 2.2.1 Superstructure definitions*

b = superstructure breadth, in metres, *see Figure 2.2.1 Superstructure definitions*

U = shock front velocity, in m/s.

2.5.9 Pressure distributions for the faces of the superstructure block are given in *Figure 2.2.3 Pressure distribution*, together with the overall pressure acting on the block which is obtained by subtracting the forces on the rear face from those on the front.

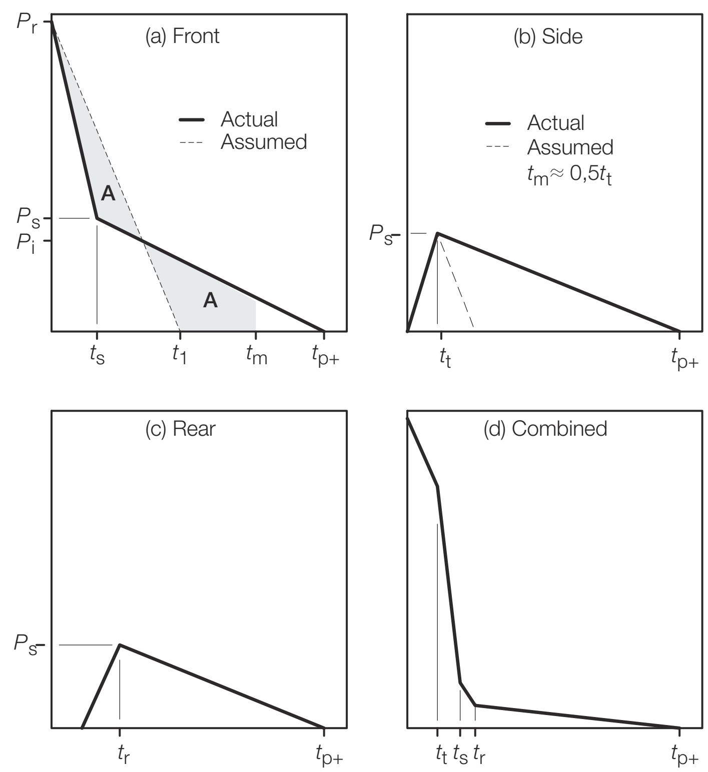


Figure 2.2.3 Pressure distribution

2.6 Nuclear threats

2.6.1 An atmospheric nuclear explosion is most likely to occur at some height above ground level at a location known as ground zero, which may be optimised to produce maximum damage effects. The blast wave is reflected from the surface and at a certain distance from ground zero, primary reflected waves combine to form a vertical 'mach' front or stem that propagates outwards from ground zero with diminishing intensity. The peak blast incident over pressure P_i can be determined from *Vol 1, Pt 4, Ch 2, 2.3 Notation assessment levels and methodology*.

2.7 Fuel air pressure loads

2.7.1 In general a structure designed to resist a moderate degree of nuclear blast will also have a reasonable resistance to fuel air threats and calculations is not normally required.

2.7.2 Where there is a risk of fuel air explosions, and for ships for which there is no nuclear threat position required, consideration needs to be given to the blast wave characteristics of such explosions, *see also Vol 1, Pt 4, Ch 2, 3.1 General*.

2.7.3 The effects of temperature on the material of the structure due to fuel air threats are to be considered using the structure surface temperature.

2.8 Conventional explosive pressure loads

2.8.1 Blast waves caused by free field explosions in air are dependent upon the mass shape and type of explosive, the distance from the target and the height of the burst. As blast waves travel through air, rapid variations occur in pressure, density, temperature and particle velocity.

2.8.2 For a given high explosive of an equivalent TNT mass at a direct distance from the target Section *Vol 1, Pt 4, Ch 2, 2.3 Notation assessment levels and methodology* can be used to determine the blast parameters.

2.9 Structural assessment

2.9.1 The rules for the **EB1** and **EB2** structural assessment are based on the assumption that the structure can be idealised as a single degree of freedom system. They assume that there is no significant loading on the superstructure or ship's sides at the time of the blast. In cases where there are significant lateral loadings or concentrated point loads or fluids, the natural frequency and strength of the structure will be specially considered.

2.9.2 The acceptance criteria based contained in this section assume that the structure is loaded beyond its elastic limit but not such that significant deformations result.

2.9.3 For plating the thickness is not to be less than:

$$t = \sqrt{\frac{f_{\mathrm{DLF}} P_{\mathrm{p}} l s^2}{6 f_{\sigma}\, \sigma_o \left(s + \mathrm{f}_{\mathrm{p}} \mathrm{l}\right)}}\ \mathrm{mm}$$

where

l = the length of the plate panel, in metres

s = width of the panel, in mm (short span length)

σ_o = yield stress of the material, N/mm^2

f_p = plate aspect ratio factor, *see Table 2.2.2 Plate factors*

f_σ = stress factor

= 1,3 for $\sigma_o \leq 300$ N/mm^2

= 1,2 for $\sigma_o > 300$ N/mm^2

P_p = the peak pressure, P_r, for the front of the superstructure, or P_s for the top sides and rear, as defined in *Vol 1, Pt 4, Ch 2, 2.5 Blast pressure loads*, in KN/m

f_{DLF} = dynamic load factor to be determined from *Vol 1, Pt 6, Ch 2, 5 Dynamic loading*:

= for superstructure front and ship sides using a linearly decreasing load with initially:

= $t_1 = P_r t_s / P_s$ seconds

= if t_m determined from *Vol 1, Pt 6, Ch 2, 5 Dynamic loading* is greater than 1,1 $P_r t_s / P_s$ then f_{DLF}, is to be recalculated such that:

= $$t_1 = t_{\mathrm{s}} + \frac{P_{\mathrm{s}}}{P_{\mathrm{r}}}\left(t_{\mathrm{p}} - t_{\mathrm{m}}\left(\frac{t_{\mathrm{p}+} - t_{\mathrm{m}}}{t_{\mathrm{p}+} - t_{\mathrm{s}}}\right)\right)\ \mathrm{seconds}$$

= For superstructure top, sides and rear using a triangular load with:

where

= $t_1 = 2t_t$ seconds

= $t_1 = 2t_r$ seconds as appropriate.

= where

P_r = peak reflected pressure as defined in *Vol 1, Pt 4, Ch 2, 2.5 Blast pressure loads 2.5.3*

P_s = stagnation pressure, as defined in *Vol 1, Pt 4, Ch 2, 2.5 Blast pressure loads 2.5.6*

t_m = time at which maximum deflection occurs

t_{p+} = positive blast pulse duration

t_s = corresponding time at stagnation pressure, P_s.

Table 2.2.2 Plate factors

Aspect ratio (A_R)	f_p
1,0	1000
0,9	916
0,8	858
0,7	817
0,6	775
<0,5	750

2.9.4 The minimum edge through thickness area of the plate is not to be less than:

$$A_\tau = \frac{1}{100s\ \tau_o}\left(6f_{p1}t^2\sigma_o\left(s + f_p l\right) + f_{p2}P_{tm}l\,s^2\right)\ \mathrm{cm}^2$$

where

= t, σ_o, l, s are given in *Vol 1, Pt 4, Ch 2, 2.9 Structural assessment 2.9.3*

τ_o = shear yield stress in N/mm^2

P_{tm} = Pressure at the time of maximum displacement, t_m, in kN/m^2 based on assumed pressure distribution.

f_{p1},f_{p2} = shear load factors, given in *Table 2.2.3 Plate shear factors*.

Table 2.2.3 Plate shear factors

Aspect ratios/ l	short span sides		long span side l	
	f_{p1}	f_{p2}	f_{p1}	f_{p2}
1,0	0,18	0,07	0,18	0,07
0,9	0,16	0,06	0,20	0,08
0,8	0,14	0,06	0,22	0,08
0,7	0,13	0,05	0,24	0,08
0,6	0,11	0,04	0,26	0,09
0,5	0,09	0,04	0,28	0,09

2.9.5 The stiffener and plate combination is considered to be satisfactory if the plastic modulus of the beam plate combination is greater than:

$$Z_{\mathrm{p}} = \frac{\mathrm{f_{DLF} P_p l s l_e}}{\mathrm{f_{bz} f}_{\sigma}\, \sigma_{\mathrm{o}}} \mathrm{cm}^3$$

where

P_{p}, f_{DLF}, f_{σ} and σ_{o} are given in *Vol 1, Pt 4, Ch 2, 2.9 Structural assessment 2.9.3*

Z_{p} = plastic section modulus of the stiffener and attached plate, in cm^3

l_{e} = effective length of the beam, in metres

l = the length of the beam, in metres

$\mathrm{f_{bz}}$ = beam support factor

= 12 for fully fixed

= 8 for simply supported

s = spacing of the beams, in mm.

2.9.6 The maximum elastic deflection given by:

$$\delta_{\chi} = 10^5 \frac{f_{\mathrm{DLF}} P_{\mathrm{p}} l s l_{\mathrm{e}}{}^3}{f_{\mathrm{bd}} E I} \mathrm{mm}$$

is not to be greater than

$$\delta_{\max} = \frac{1000 l}{115} \mathrm{mm}$$

where

P_{p}, $\mathrm{f_{DLF}}$, s, l and l_{e} are given in *Vol 1, Pt 4, Ch 2, 2.9 Structural assessment 2.9.3*

I = second moment of inertia cm^4

$\mathrm{f_{bd}}$ = beam support factor

= 384 for fully fixed

= 76,8 for simply supported.

2.9.7 The shear area of the stiffener web is not to be less than:

$$A_{\tau} = \frac{1}{100\, \tau_{\mathrm{o}}} \left(\frac{\mathrm{f}_{\mathrm{s}1} \mathrm{f_{bz} Z_p}\, \sigma_{\mathrm{o}}}{1000\, \mathrm{l_e}} + \mathrm{f}_{\mathrm{s}2} \mathrm{P_{tm}} \mathrm{ls} \right) \mathrm{cm}^2$$

where

= Z_{p}, σ_{o}, l_{e}, l, s are given in *Vol 1, Pt 4, Ch 2, 2.9 Structural assessment 2.9.3*

= τ_{o}, P_{tm} are given in *Vol 1, Pt 4, Ch 2, 2.9 Structural assessment 2.9.4*

= $f_{\mathrm{s}\,1}$, $f_{\mathrm{s}\,2}$ = shear load factors, given in *Table 2.2.4 Beam shear factors*.

= $f_{\mathrm{b\,z}}$ is given in *Vol 1, Pt 4, Ch 2, 2.9 Structural assessment 2.9.5*.

Table 2.2.4 Beam shear factors

Beam type	Location	f_{s1}	f_{s2}
Simply supported	Both ends	0,39	0,11
Fixed ends	Both ends	0,36	0,14

Simple and fixed	Fixed end	0,43	0,12
	Simple support	0,26	0,19

2.9.8 Direct calculations or analyses based on the elastoplastic or plastic response of structure using a dynamic load factor or finite element approach will be specially considered. The designers' calculations are to be submitted for approval.

2.9.9 In addition to the assessment of plating and stiffeners, the global capability of superstructure and above water structure are to be assessed. The designers' calculations are to be submitted.

2.10 Design considerations

2.10.1 To minimise the effects of external blast, protrusions from the superstructure are to be kept to a minimum.

2.10.2 Re-entrant corners are to be avoided, where this is impractical they are to be covered by a blast deflecting plate, or be constructed such that the included angle between orthogonal faces is to be as large as possible.

2.10.3 Where the clear air gap between superstructure blocks is less than $0,1L_R$, the interaction under external blast loading will be specially considered.

■ *Section 3* Internal blast

3.1 General

3.1.1 Internal blast is defined as that which occurs from detonation of a high explosive from a hostile weapon or detonation of a ship's own ammunition inside the hull envelope. In an internal explosive loading situation the loading on a boundary can be characterised by a series of decaying reflected pressure waves (blast impulses) followed by the rapid formation of a slowly decaying static pressure (Quasi static pressure QSP) as shown in *Figure 2.3.1 Typical blast pressure time history*.

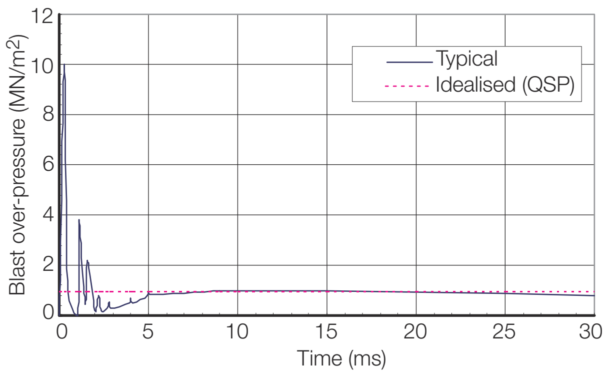


Figure 2.3.1 Typical blast pressure time history

3.1.2 The magnitude of the initial blast impulse is related to the distance from structure under consideration to the explosion. The reflections are a function of the compartment geometry. The QSP is dependent on the compartment volume with the rate of decay related to the vent area.

3.2 Threat level determination

3.2.1 The threat protection levels for a given vessel should be determined through a vulnerability analysis against customer specified threat weapons. In the absence of such a study the following levels may be used as a guide:

- Level **I** Watertight bulkheads at $R_{4N} \geq 1$ and zone bulkheads at $R_{4N} > 1$
- Level **II** Watertight bulkheads at $R_{4N} \geq 1{,}5$ and zone bulkheads at $R_{4N} > 2$
- Level **III** Watertight bulkheads at $R_{4N} > 3$ and zone bulkheads at $R_{4N} > 3$

R_{4N} is the normalised blast resistance 2,5 m high, 4 mm thick, mild steel, fillet welded bulkhead.

3.3 Notation assessment levels and methodology

3.3.1 The Rules are aimed at limiting the spread of blast damage to compartments adjacent to that directly affected by the explosion. For an explosion where the ratio of charge size to compartment volume is small, it may be possible to limit the damage to the affected compartment.

3.3.2 Ships complying with the requirements of this section will be eligible for the **IB1** notation. Where further analysis or testing is used to determine the blast resistance of the structure an **IB2** notation may be assigned.

3.3.3 For the **IB2** notation, the assumptions made for initial deformations are to be submitted. Where these differ from normal ship building practice, the details are to be recorded on the approved plan.

3.3.4 There are specific scenarios such as fuel air explosions within aircraft hangars where the internal blast wave characteristics will need to be specially considered on request.

3.4 Materials

3.4.1 For level **III** protection all plate bulkhead materials are to have a sulphur content less than 0,01 per cent. This may be achieved by the specification of through thickness properties in accordance with the requirements of *Ch 3, 8 Plates with specified through thickness properties* of Rules for Materials.

3.4.2 Consideration should be given to the use of austenitic electrodes for fillet welding of ferritic materials subject to high strain loading. In selecting the filler material, consideration is to be given to the material's proof strength and elongation; the 0,2 per cent proof stress of the filler material as welded is to match the strength of the ferritic parent steel plate, and the elongation to failure is to be as great as possible. Care should be taken to ensure that coatings are maintained as far as practicable. Where such materials are in wet or immersed areas, special attention is to be given to corrosion protection and the selection of a material that is not prone to chemical or electro-chemical attack. Details of the weld procedure are to be submitted for approval.

3.5 Quasi static pressure

3.5.1 Structural failure can be caused by either the impulsive loading or the dynamic loading imparted by the combined blast waves and QSP. Normally if the weapon is sufficiently large to cause failure by impulse it will also fail under a dynamic loading assessment based on a step function to the QSP level. For the purposes of general design the step function to the QSP level assessment can be used as the loading criteria to determine failure. Safety or mission critical areas should be specially considered.

3.5.2 The actual threat level used in the calculation and areas of the ship to be protected are to be specified by the Owner and will remain confidential to LR.

3.5.3 The QSP can be determined from the following:

$$P_{qs} = 2{,}25\,(W_e N)^{0{,}72} \times 10^3 \text{ kN/m}^2$$

where

P_{qs} = quasi static pressure, in kN/m^2

W_e = weapon equivalent weight of TNT, in kg

V = free compartment volume, in m^3.

3.6 Structural resistance

3.6.1 The blast resistance for a given bulkhead material, thickness and joint style can be determined as a proportion of 2,5 m high, 4 mm thick, mild steel, fillet welded bulkhead using the following formula based on a combination of explosive tests and analytical techniques:

$$R_{4N} = (K_j + K_m)\, t / l$$

where

= R_{4N} is the normalised blast resistance 2,5 m high, 4 mm thick, mild steel, fillet welded bulkhead

= K_m is the material type factor, *see Table 2.3.1 Material type factor, K_m*

= K_j is the joint type factor, *see Table 2.3.2 Joint type factor, K_j*

= t is the thickness of steel, in metres

= l is the short span length, in metres.

Table 2.3.1 Material type factor, K_m

Steel grade	K_m
A, D, E, AH32, AH36	0
DH32, EH32	86
DH36, EH36	196

Table 2.3.2 Joint type factor, K_j

Joint style	K_j	Note
Normal fillet weld	625	Valid up for $t_{bh} \leq 8$ mm
Full penetration weld	665	Valid for $t_{bh} \leq 12$ mm
Austenitic fillet weld	701	Valid for $t_{bh} \leq 6$ mm
Note Values of K_j up to 1200 can be achieved using blast resistant bulkhead designs.		

3.6.2 The primary mode of failure for bulkhead structures is through the edge connection. Alternatives to the basic fillet weld have been assessed and incorporated in the joint type factor presented in *Table 2.3.2 Joint type factor, K_j*.

3.6.3 Alternative joint types may be used but are to be categorised using a dynamic joint test and blast assessment. For novel designs a further large scale controlled blast test of the proposed arrangement is to be tested. LR can provide details of the test and analysis requirements on request.

3.7 Bulkhead arrangements

3.7.1 Piping that passes through the bulkhead is to be fitted with expansion pieces either side of the bulkhead. In addition, piping and other penetrations are to be arranged at the edges of the bulkhead where the relative movement is less as shown in *Figure 2.3.2 Blast bulkhead penetrations*.

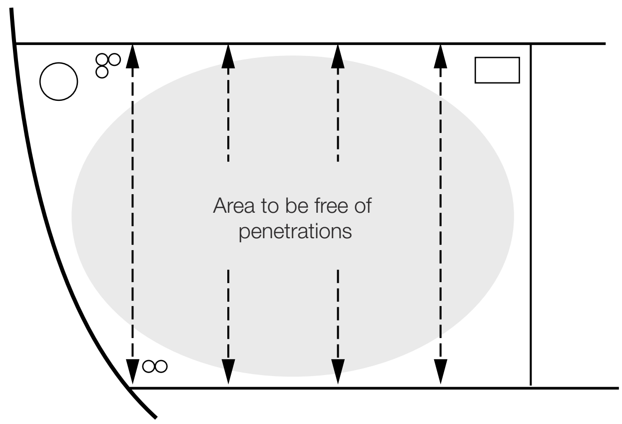


Figure 2.3.2 Blast bulkhead penetrations

3.7.2 Bulkhead attachments are to be kept to a minimum and designed for good dynamic performance.

3.7.3 The strength of doors if fitted will be specially considered. Steps are to be taken to prevent their detachment from or pushing through the surrounding structure.

3.7.4 Consideration should be given to the use of flexible collars around deep girder penetrations through the blast bulkhead to allow relative movement but retain watertight or gas-tight integrity.

3.7.5 Under blast loading, large displacements of the bulkhead may occur. Any nearby structure or equipment is to be located so as to provide a minimum clearance of 350 mm from the bulkhead. This distance is generally appropriate for deck heights of between 2 m and 3 m. The minimum clearance for other deck heights will be specifically considered.

■ *Section 4*
Fragmentation protection

4.1 General

4.1.1 This section does not deal with the loss of structural strength due to material perforation. It is only concerned with fragmentation protection of equipment and personnel within critical compartments and potentially critical pipe and cable runs.

4.1.2 Fragment and small arms penetrators can be stopped by the use of structure designed to prevent penetration, either through the use of increased thickness of normal structural materials, suitable siting of compartments, addition of armour (non-structural) materials, or even the use of armour material that can take structural loads.

4.1.3 The Rules give design data based on fragment penetration equations for three representative threats. The selection and use of fragment penetration equations or computer modelling for other threats will be considered provided they are carried out by a competent body which has relevant experience and employs recognised procedures.

4.1.4 For fragmentation protection to be effective, materials within the ship forming part of the ship's equipment and outfit shall be of a type that is not prone to the generation of secondary fragments or 'splinters'. Materials such as wood, brittle plastics and brittle cast materials are not to be used in protected compartments. Where the use of such materials is essential, consideration may be given to the use of bonded splinter-retaining membranes.

4.1.5 RATTAM is defined as the response to attack on ammunition and describes protection fitted externally to the ship to prevent the penetration of particular threats which may cause damage, principally to magazines. Similar protection may also be fitted to protect other critical compartments, both are covered by the **SP** notation.

4.2 Threat level determination

4.2.1 The threat may be classified as either small arms fire or fragments from the casing of shells or warheads ('shrapnel' or 'splinters') capable of perforating the ship's structure and thus causing damage to equipment or casualties amongst personnel.

4.2.2 Three levels of protection are shown in *Table 2.4.1 Fragment threat types*. They are from a combination of internally and externally detonating threats. Alternative levels will be considered in accordance with *Vol 1, Pt 4, Ch 2, 4.5 Structural requirements 4.5.2*.

4.2.3 The actual threat level and type used in the calculation and the areas of the ship to be protected are to be specified by the Owner and will remain confidential to LR.

Table 2.4.1 Fragment threat types

Level	Typical threat origin	Fragment weight (g)	Initial fragment velocity (m/s)
I	Aircraft fired 30 mm high explosive (HE) cannon shell	up to 1 g	less than 1250
II	Proximity detonating 105 mm Artillery round	up to 15 g	less than 1250
III	Sea Skimming (SAP) missile	up to 55 g	less than 1400

4.2.4 The Level I threat is assumed to detonate on impact with the ship's structure in the act of which it will penetrate the outer skin of the vessel. Fragmentation protection will reduce the risk of fragments penetrating additional compartments. The ends, internal sides and decks of critical compartments are in general to be fitted with protection, an example of which is shown in *Figure 2.4.1 Level I arrangement*, *see also Vol 1, Pt 4, Ch 2, 4.3 Notation assessment levels and methodology 4.3.2*. The outer skin of the ship may be strengthened to resist the shell in accordance with the requirements for the **SP** notation, however it will usually require a significant amount of armour.

4.2.5 Level II considers a threat posed by an externally detonating shell. Strengthening is, in general, to be fitted to the external skin of the ship to protect the critical internal spaces, an example of which is shown in *Figure 2.4.2 Level II arrangement*, *see also Vol 1, Pt 4, Ch 2, 4.3 Notation assessment levels and methodology 4.3.2*. For this level of protection a stand off distance for the weapon is to be specified by the Owner.

4.2.6 The Level III threat is a generic weapon based on a sea skimming anti-ship weapon with a semi armour piercing, (SAP) warhead that detonates within the hull. Fragmentation protection is intended to reduce the risk of fragments penetrating additional compartments. The considerable amount of protection required will normally mean that protection is only fitted at zone boundaries to limit the longitudinal spread of fragments. *See* example in *Figure 2.4.3 Level III arrangement* and also *Vol 1, Pt 4, Ch 2, 4.3 Notation assessment levels and methodology 4.3.2*.

4.2.7 The examples given in *Figure 2.4.1 Level I arrangement* show a compartment immediately under the main deck with deckhouse over subject to a side-on attack. Where the critical compartment is fitted directly below an external deck, in a deckhouse or the threat is directly above the compartment, protection is to be arranged using the principles given in examples in *Figure 2.4.1 Level I arrangement*.

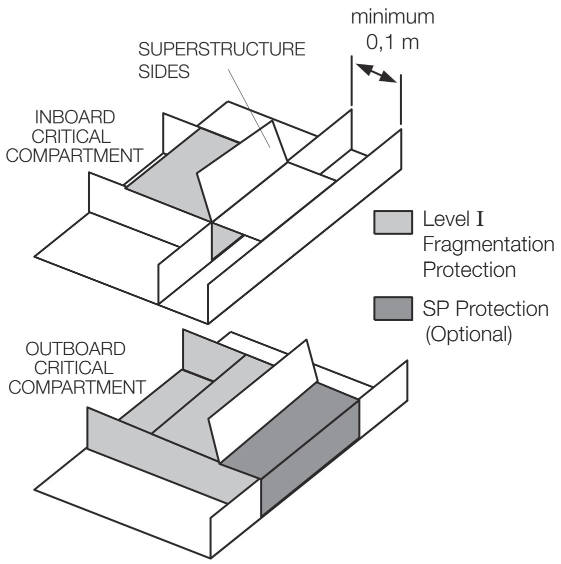


Figure 2.4.1 Level I arrangement

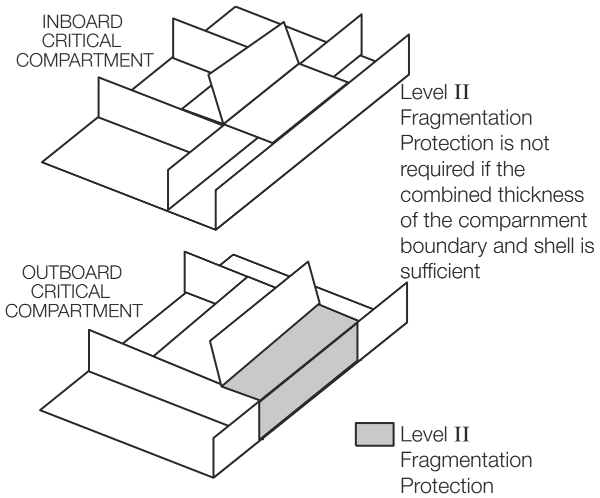


Figure 2.4.2 Level II arrangement

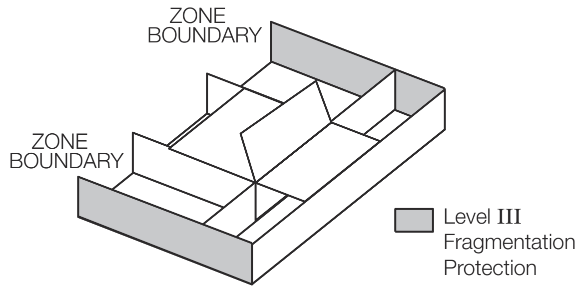


Figure 2.4.3 Level III arrangement

4.3 Notation assessment levels and methodology

4.3.1 The fragmentation protection **FP1** and **FP2** notations are assigned for ships which have protection fitted to resist fragments from the casing of a shell or warhead. The small arms protection, **SP** notation is assigned for ships fitted with protection to resist the penetration of small arms fire into the hull. For ships where the fragmentation resistance is carried out using the Tables and graphs of this section an **FP1** notation is assigned. Where fragmentation testing or analysis is used to determine the fragmentation resistance required a **FP2** notation is assigned.

4.3.2 The pressure produced by a Level **I** threat is such that an **IB** notation is not required. The Level **II** threat is external and of a level such that an **EB** notation will not be required. A Level **III** threat will require the effect of the internal blast pressure on the structure to be considered and **IB** and **RSA** notations will generally be required.

4.4 Information required

4.4.1 For each threat level it will be necessary to identify the critical compartments requiring protection, plus the critical pipe and cable runs where appropriate. Plans are to be provided showing the location and manner of all fragmentation and terrorist attack protection.

4.4.2 Where alternative tests or calculations have been carried out full details are to be submitted. They are to include details of the organisation involved, their experience, test or calculation procedures and the program or equations used.

4.5 Structural requirements

4.5.1 Where different threats, materials or multiple plate arrays are fitted alternative methods may be used to determine the fragmentation resistance, for example:

- Penetration equations.
- Finite element and fluid-codes.
- Experimental methods.

Ascending the levels of calculation complexity is not simply a matter of increased cost in design, the increased complexity potentially offers the reward of reduced protection requirement for the given threats.

4.5.2 Armour spaced normal to the threat can reduce the total thickness by up to 30 per cent. It may also be effective for bullets provided the gap between plates is greater than 1,0 m.

4.5.3 For Level **I** fragmentation protection, the equivalent thickness of steel is to be in accordance with *Table 2.4.2 Level I fragmentation protection*.

4.5.4 For Level **II** fragmentation protection, the equivalent thickness of steel is to be determined from *Figure 2.4.4 Level II fragmentation protection*.

Table 2.4.2 Level I fragmentation protection

Material yield strength N/mm^2	Transverse bulkhead or deck thickness mm	Longitudinal bulkhead thickness mm
235	6,5	6,0
355	6,0	5,5
550	5,5	5,0
RHA	5,0	4,5
Note RHA is defined as rolled homogenous armour.		

4.5.5 For Level **III** fragmentation protection, the equivalent thickness of steel is to be determined from *Figure 2.4.5 Level III fragmentation protection*. Protection will normally be required to be provided by several bulkheads or specific armour and the graph can serve only as a guide. The structural protection for this type of threat will generally be specially considered based on the particular weapon characteristics and protection arrangements. It should also be noted that many modern missiles generate controlled fragments which will need special consideration.

4.5.6 The graphs are produced based on a 50 per cent probability of perforation for penetrators perpendicular to the target.

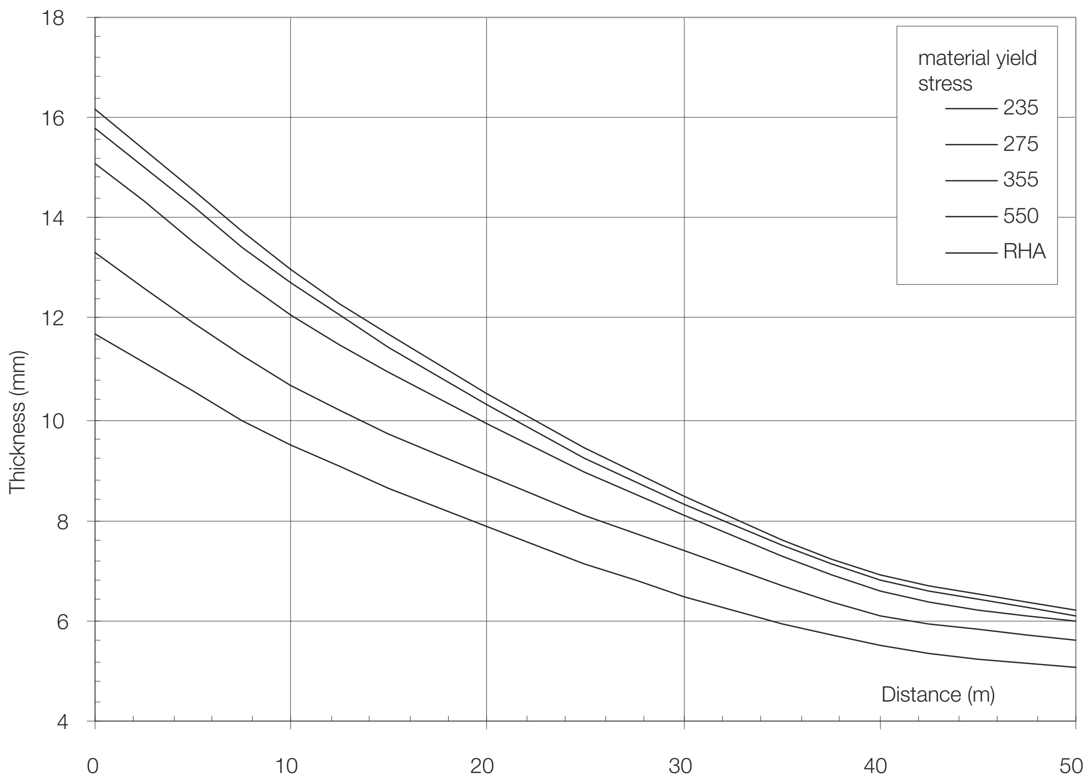


Figure 2.4.4 Level II fragmentation protection

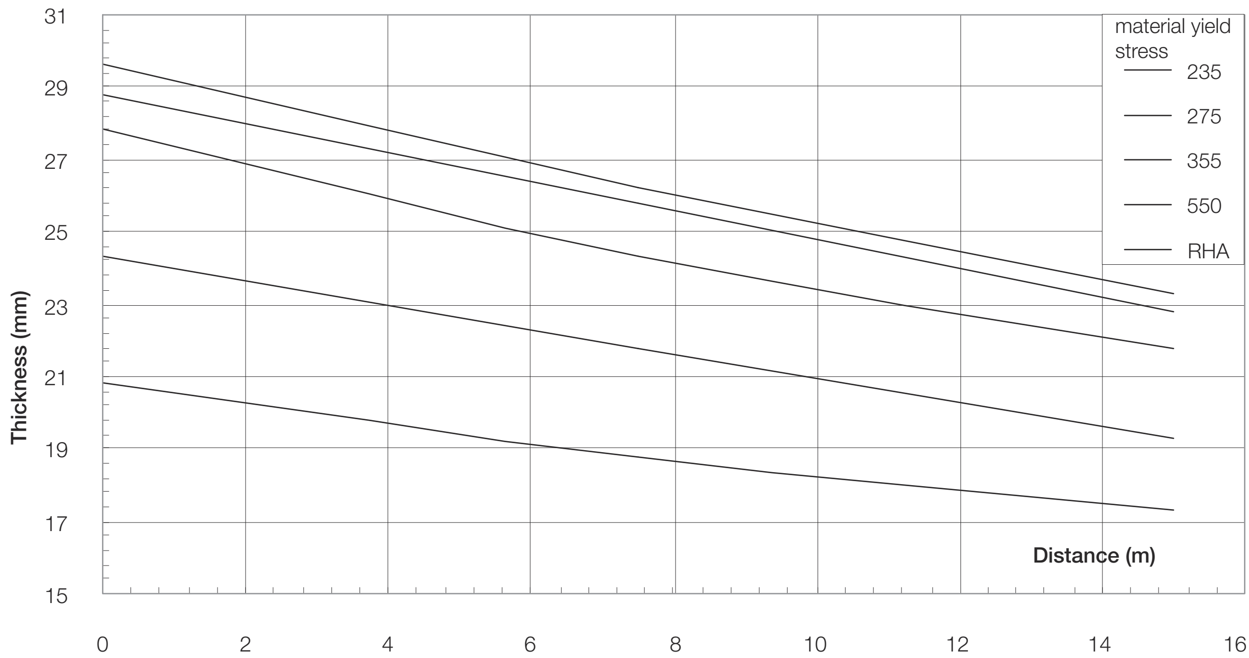


Figure 2.4.5 Level III fragmentation protection

■ *Section 5* Underwater explosion (shock)

5.1 General

5.1.1 There are two principal loading mechanisms associated with the underwater detonation of a conventional high explosive ordnance:

- shock wave loading;
- bubble flow loading.

5.1.2 The energy released is in general, equally divided between shock wave energy and the energy contained within the superheated high pressure bubble of gaseous explosion products.

5.1.3 The shock wave generated as the detonation wave passes into the water is a highly non-linear pressure pulse which propagates at a speed well in excess of the speed of sound in water (approximately 1500 m/s). However, within a few charge radii of the detonation point, it can be mathematically defined as an acoustic pressure pulse travelling at the speed of sound. Its amplitude falls off inversely with distance and its profile can be characterised by a pulse which has an infinite rise to a peak pressure followed by an exponential decay. The peak value and decay rate at a given field point are given by the similitude equations/coefficients for the explosive material.

5.1.4 In the meantime, the gas bubble begins to expand against the ambient hydrostatic pressure displacing water radially outward as incompressible flow. As it expands, it loses pressure and temperature but the inertia of the outwardly flowing water leads to an overshoot of the equilibrium state so that at maximum bubble radius, the gas pressure is well below the ambient. This initiates the collapse sequence, the gas bubble is recompressed, slowly at first but then rapidly, to a minimum volume by the hydrostatic forces. Because of the generation of a large pressure in the bubble during this stage the bubble begins to expand again and several other cycles may follow. The gas bubble and water interaction can be thought of as a gas spring - mass system. It has a periodicity associated with it but because of energy losses during the process, the spring constant and mass changes over each cycle leading to a change in the periodicity. At each minimum, that is, each recompression, additional pressure pulses are emitted which become weaker with each oscillation as shown in *Figure 2.5.1 Shock wave bubble pulse*.

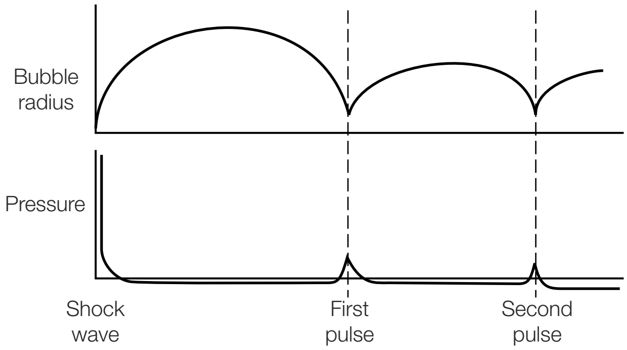


Figure 2.5.1 Shock wave bubble pulse

5.1.5 The bubble is pulsating in a gravitational field and will have a tendency to migrate to the water/air boundary (the free surface). However, this bodily motion of the bubble centre may be influenced by the proximity of other boundaries such as the seabed or a nearby ship structure. The rate at which a bubble will migrate to the free surface is a function of the buoyancy forces generated when it is at its maxima and of the drag forces it experiences as it moves through the water. Because these drag forces are small when the bubble is at its minima, it tends to migrate vertically upwards more rapidly when at its smallest volume.

5.1.6 The fluid flow generated by the bubble dynamics is an important loading mechanism for a structure, within its sphere of influence. Normally bubble loading can be ignored if the bubble never approaches within a distance of around ten times the maximum bubble radius. The important feature of the bubble loading is its low frequency which is ideally suited to induce ship hull girder flexural motion. This flexural motion is commonly referred to as hull girder whipping. This loading mechanism is dealt with in *Vol 1, Pt 4, Ch 2, 6 Whipping*. If the bubble is within one bubble radius of the ship structure, it is likely to form a jet which will impact on the structure. This bubble collapse mechanism will cause extensive local damage. It is generally not possible to efficiently design against this loading event for a **NS2** or **NS3** ship. For a **NS1** ship there may be sufficient residual strength to withstand such damage, but the extent of the damage will need to be determined by a specialist calculation and the capability of the hull using a residual strength assessment, *see Vol 1, Pt 4, Ch 2, 7 Residual strength*.

5.1.7 The shock wave loading is greatest at a point on the structure nearest to the detonation event and because of the fall-off with distance and the narrowness of the pulse width, it can be thought of as a local loading event. (In contrast, the bubble induced whipping of the hull girder is considered a global loading event.) The remainder of this section will focus on the shock loading event only.

5.1.8 There are no simple analytical or numerical techniques for reliably determining the shock resistance of a structure. A measure of the resistance to shock loading can be achieved by good design of the details of the structure to avoid stress concentrations which may lead to rupture. It is also possible to ensure that the plating thickness is matched to the assumed performance of the joints using a simple damage law. The inertial loads on the ship's structure caused by the equipment and its seatings can be determined by time domain analysis.

5.1.9 The shock performance of a ship's hull structure can be assessed solely by conducting shock tests (usually at scale). However, cost usually precludes this approach and a better strategy is to combine tests to determine failure criteria with numerical modelling using Finite Element methods. This complementary experiment /numerical simulation approach reduces the amount of testing required and also provides a method for extrapolating to full scale from scaled experiments.

5.1.10 Generally, for a normal ship structure, the explosion required to cause uncontrollable flooding or total loss of propulsive power or loss of mission system effectiveness (radars, electronics, etc.) is much less than that required to cause failure of a hull designed for normal sea loads.

5.1.11 Due to operational requirements, some vessel types, such as minesweepers, will be required to resist repeated shock loading at a specified level without degradation of the system or structural performance. Such vessels will also be expected to survive a single attack at a considerably higher shock loading level.

5.2 Threat level determination

5.2.1 The actual threat level used in the calculation of performance and the areas of the ship to be protected by this design method are to be specified by the Owner and will remain confidential to LR.

5.2.2 Loading levels may be specified with varying degrees of structural and system degradation to define the shock performance of the vessel. An important consideration is the balance that has to be achieved between system functionality and structural performance.

5.2.3 Two performance bounds can be considered for the shock response of structure:

- The first performance bound (lower bound) relates to the onset of material yield (assuming that careful design has ensured that no buckling will occur before this state is reached). This level is useful to know as it may have consequences for system functionality. For example, there may be problems associated with equipment mis-alignment because of the permanent set of the supporting structure.
- The second performance bound (upper bound) relates to removal or rupture of material; this being the loading level at which there is no longer sufficient residual hull girder strength to resist normal environmental loading. This is addressed in a separate assessment which is defined by the residual strength notations **RSA1**, **RSA2** or **RSA3** in *Vol 1, Pt 4, Ch 2, 7 Residual strength*. In conventional naval ships, this upper bound will be significantly higher; but there will be little, if any, system functionality.

5.3 Notation assessment methodology

5.3.1 The shock performance required is to be specified by the Owner and is to include requirements for:

- Local strength assessment;
- Detailed design;
- Seat design, shock mounts and system hangers;
- Hull valve design and integration;
- Global strength assessment;
- Shock qualification/testing of equipment;
- 1st of class shock trial.

It is recommended that seats, valves, piping and equipment are categorised into:

- equipment required to be capable of operation after the specified shock event;
- equipment that is required to be captive, with reduced or no operational capability after the specified shock event;
- equipment which has no requirements after the specified shock event.

See also Vol 2, Pt 1, Ch 1, 3.1 Categories 3.1.1.

5.3.2 Ships that comply with the minimum or enhanced requirements of this Section will be eligible for the shock notation **SH**.

5.3.3 For ships where the machinery is in class (**LMC** notation), and shock requirements for machinery and equipment are specified, the requirements of *Vol 2, Pt 1, Ch 3, 4.11 Machinery shock arrangements* are to be complied with.

5.3.4 For the minimum shock capability, the design emphasis should focus on maintaining a high level of system functionality and reducing the risk of flooding.

5.3.5 For the assignment of the **SH** notation, the minimum requirement is for the structure to be designed to resist normal environmental loads in accordance with the Rules. For **NS1** ships, the inherent ruggedness in the Rules is sufficient for the structure to resist a low level threat. For **NS2** and **NS3** ships, the integrity of the hull plate and stiffeners is to be verified, using the simple formulae for pressure in *Vol 1, Pt 4, Ch 2, 5.4 Local strength assessment 5.4.1*, and comparing the response to a specified standard. In addition, the hull valves below the waterline are to comply with the requirements of *Vol 1, Pt 4, Ch 2, 5.8 Design guidance for hull valves, piping and seals*.

5.3.6 The minimum local assessment required by *Vol 1, Pt 4, Ch 2, 5.3 Notation assessment methodology 5.3.5* can be enhanced by undertaking a more complex assessment as defined in *Vol 1, Pt 4, Ch 2, 5.4 Local strength assessment*, which accurately models the physics of the rapid, dynamic, fluid structure interaction problem.

5.3.7 In addition to the analysis, the **SH** notation can be enhanced by selecting detail design requirements to reduce the risk of fracture initiation and structural collapse, based on historical work on shock. Details are provided in *Vol 1, Pt 4, Ch 2, 5.5 Detail design guidance*.

5.3.8 The **SH** notation may be further enhanced by undertaking shock trials in accordance with established procedures, on the first ship in the class. The magnitude of the test is normally less than the design value for the hull and at a level that is appropriate for the equipment and systems.

5.3.9 Global assessment may be undertaken for the **SH** notation, using the residual strength procedures outlined in *Vol 1, Pt 4, Ch 2, 7 Residual strength* with the extent of damage being defined from the results of the local strength assessment rather than the damage radii. For the **RSA1** procedure, the damaged structure is to be removed from the analysis. For the **RSA2** or **RSA3** procedure, if the damage is limited, the geometry of the damaged structure can be modelled and if the damage is severe, the structure is to be removed from the analysis. The structure is considered acceptable when the hull girder is able to withstand the design loads as specified in *Vol 1, Pt 5 Environmental Loads*.

5.4 Local strength assessment

5.4.1 For the notation **SH**, a simple analysis can be performed which allows the motion response at any point in the ship to be determined. This can be derived from experimental results or the Taylor plate equations given below. Once the motion response is known, the damage potential can be determined by comparing the response to a specified standard.

Maximum velocity

$$V_{max} = \frac{2P_{\mathrm{m}}}{\rho\ \mathrm{c}} z^{u} \text{ m/s}$$

Time to maximum velocity

$$t_{max} = \frac{m}{\rho\ \mathrm{c}}\left(\frac{1}{1-z}\right)\log_{\mathrm{e}}\left(\frac{1}{z}\right) \text{ seconds}$$

where

$z = \dfrac{m}{\rho\ \mathrm{c}\,\theta}$

$u = \dfrac{z}{1-z}$

θ = decay constant of explosive charge in seconds

P_{m} = peak pressure in N/mm^2

ρ = density of water in kg/m^3

c = speed of sound in water in m/s

m = structural mass per unit area in kg/m^3.

5.4.2 A more complex assessment method can be used to enhance the **SH** notation. Methods can be used which accurately model the physics of the shock event. At the simplest level, a finite element model of the structure coupled with a suitable boundary element from proprietary software may be used.

5.4.3 For complex ships such as multi-hull designs a boundary element approach may not be suitable and a volume element approach should be used. Also, if non-linear fluid behaviour is important (i.e. hull cavitation or bulk cavitation), then a volume element approach should be used, unless the finite element or boundary element code used has a suitable cavitation model.

5.4.4 The assessment method or analysis used should be validated against shock trial results and the evidence made available. As an alternative to analysis, full or large-scale shock trials of a section of the ship can be used to validate the proposed design. For novel design arrangements or ship types, a combination of trials and analysis may be necessary, the requirements of which will depend on the threat level and type of structure or ship design.

5.4.5 Any finite element analysis performed for local strength assessment is to be in accordance with the requirement of this Section for assignment of the **SH** notation.

5.4.6 The extent of the analysis model is to be from about 0,35L_{R} to 0,55L_{R} and encompass at least two major compartments and three watertight bulkheads. It is to be sufficiently large to avoid reflections within the structure from the boundaries, for the threats considered. For the assessment of structural strength, the structure need only be modelled to 1,0 m above the design water line. If the model is to be used to determine equipment response, all structure within that section should be modelled.

5.4.7 The model, or versions of the model, should encompass representative integral tank arrangements and hull penetrations, stabiliser inserts, hull valves, the failure of which could lead to uncontrollable flooding. Penetrations, the failure of

which will not lead to significant flooding or damage, need not be considered. The tanks and penetrations need not actually be in the section under consideration but should be sufficiently similar to represent structure outside the region modelled.

5.4.8 All masses above 100 kg should be included in the model together with an approximation of the mounting system if applicable.

5.4.9 The model should include at least one major machinery item or raft.

5.4.10 The response of hull panels depends upon a large number of variables which are both design and attack geometry dependent. To simplify the task, the following assumptions can be made:

- The charge detonates in the worst location, perpendicular to the structure under consideration.
- All welding is continuous and there are no manufacturing or material defects in the panels.

5.4.11 During the analysis, appropriate elements are to be used to couple the fluid medium and the structural model.

5.4.12 The shock wave can be represented by an exponentially decaying, infinite rise time pressure pulse which sweeps across the structure at the speed of sound.

5.4.13 Non-linear structural modelling can be used in finite element analyses. If used, stiffeners should be modelled explicitly using shell elements of the appropriate thickness. Stiffener flanges should be modelled with at least two elements per half width or flange. Initial imperfections in the hull plating are to be taken into account prior to the dynamic loading analysis.

5.4.14 The structure is considered acceptable when:

- Elastic deflections are less than the temporary limits of machinery and systems.
- Permanent deflections are less than the limits of machinery and systems.
- Deflections and strain are less than the limits of the structure or applicability of the analysis method.

5.5 Detail design guidance

5.5.1 For enhanced shock performance, any of the following design details can be included in the design, which is based on historical shock testing and experience.

5.5.2 Tank boundaries are to be of equivalent scantlings to the hull boundaries.

5.5.3 Intermittent welding is not to be used on hull girder structure or tank boundaries below the water line or for 1 metre in way of the deck and shell connections.

5.5.4 Structural discontinuities are to be avoided and in general a minimum taper of 1:4 is to be applied to changes of structural section.

5.5.5 Bar keels are not to be fitted.

5.5.6 Tanks are to be integral with the ship's structure. For free standing tanks greater than100 litres, calculations demonstrating the capability of the tank and supporting structure are to be submitted.

5.5.7 Main machinery mounts or raft mounts are to be supported on transverse web frames or floors forming part of the transverse ring structure. *See Vol 1, Pt 3, Ch 2, 3.2 Primary members 3.2.2*

5.5.8 The size of longitudinal members passing through, or ending on, bulkheads are to be as small as possible, though still complying with the appropriate scantling requirements of *Vol 1, Pt 6, Ch 3 Scantling Determination*. Bulkhead stiffeners are to be fitted perpendicular to the shell plating.

5.5.9 Where deep longitudinal members are unavoidable, their connection to the bulkhead will be specially considered.

5.5.10 Bottom longitudinals are to be of a uniform size. Alternate large and small longitudinals are to be avoided as they may lead to high shear forces in the bulkhead.

5.5.11 Access holes in all primary framing members are to be avoided in areas of high shear stress. Where they are essential to the operation of the ship they are to be circular and fitted with appropriate stiffening or compensation.

5.5.12 Frames on the bilge are to be provided with adequate lateral support, consideration should be given to the fitting of a shock stringer.

5.5.13 Lapped connections are not to be used to connect frames to floors.

5.5.14 All bulkhead stiffeners are to end on longitudinals, *see Figure 2.5.2 Bulkhead stiffening*.

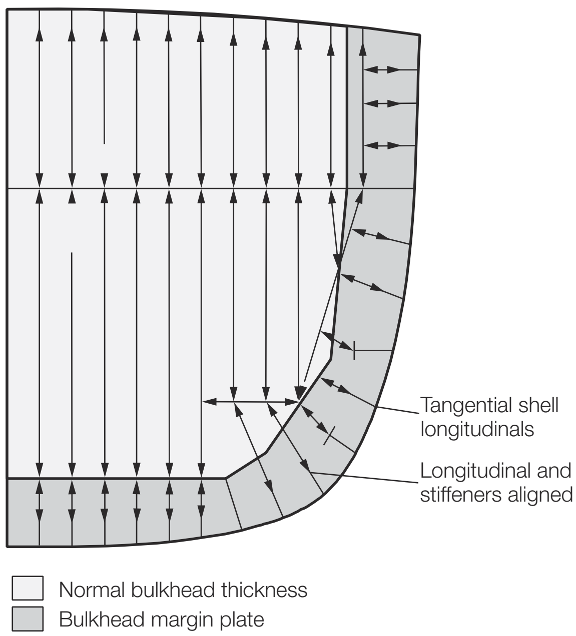


Figure 2.5.2 Bulkhead stiffening

5.5.15 In transversely framed ships, bulkhead stiffeners are to be terminated on a shock stiffener welded to the bulkhead, parallel to, and spaced 500 mm from the shell. The bulkhead plating thickness is to be suitably increased in way. The shock stringer and bulkhead plate may be replaced by a web frame of suitable scantlings.

5.5.16 Bulkhead penetrations are to be grouped, away from the side shell and kept above the water line as far as is practicable.

5.5.17 Shell frames and deck beams are to be fitted in such a way as to minimise misalignment. Brackets where fitted are to be radiused and fitted with soft toes.

5.5.18 Where the vessel is to be subjected to very high levels of shock, the following details can be included in the design.

5.5.19 Pillar bulkheads are to be used below the waterline in place of pillars.

5.5.20 It is recommended that symmetric stiffeners should be fitted to the to the underwater portion of the shell envelope.

5.5.21 Where a transverse framing system is used, the shock capability of the structure will be specially considered. Calculations supporting the use of particular design details are to be submitted.

5.5.22 All bulkhead stiffeners are to end on longitudinals, *see Figure 2.5.2 Bulkhead stiffening*. An increased thickness margin strake on bulkheads of thickness not less than 80 per cent of the adjacent shell plate thickness, the thickness of the adjacent shell stiffener or 6,5 mm. The margin plate is to have a width not less than 1,5 times the adjacent stiffener spacing or four times the depth of adjacent shell stiffeners.

5.5.23 Shell frames and deck beams are to be fitted in such a way as to minimise misalignment. The frames are to be fitted within a tolerance of 0,3 t_{fl} median line up to a maximum of 3,0 mm where t_{fl} is the greater thickness of the frames being connected. Where this is not possible, the frame is to be released over 20 t_{fl} and realigned.

5.5.24 Where brackets are fitted, similar tolerances to *Vol 1, Pt 4, Ch 2, 5.6 Seat design 5.6.5* are to be applied subject to a suitable area being provided for weld fillet, *see Figure 2.5.3 Bracket connections*. Tripping brackets or intercostal stiffeners should be used to stabilise the frame at the bracket toes. Brackets are to be radiused and fitted with soft toes.

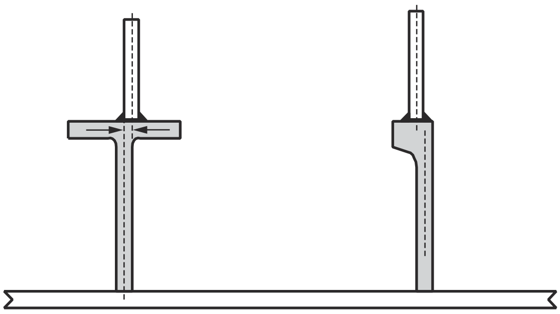


Figure 2.5.3 Bracket connections

5.5.25 The cross-sectional area of the bulkhead stiffeners at their outer ends in way of the margin plate should not be less than 60 per cent of the area of the web of the hull longitudinals to which they are attached. To achieve this requirement, the bulkhead stiffeners may be tapered between the outer end and the point at which the size is the minimum required to withstand lateral pressure. The slope of the taper is to be such that:

$A_x > 0{,}6 A_L - 2t_x/3$

where

A_x = cross-sectional area of the bulkhead stiffener at a distance x from its outer end

A_L = web area of the longitudinal, and t is the bulkhead plating thickness at x.

5.5.26 The short stiffeners above the turn of bilge should be on the same side of the bulkhead as the main bulkhead stiffeners and should end on such a stiffener, *see Figure 2.5.2 Bulkhead stiffening*. Where necessary, an additional diagonal stiffener may be worked to facilitate the arrangement.

5.6 Seat design

5.6.1 The shock notation may be enhanced by specifying that some or all of the equipment seating is to be designed to resist shock loading. Seat design should take account of the acceleration and deceleration from the shock wave; the magnitude of the shock acceleration will depend on the equipment mass, position in the ship and mounting arrangements. The seat design methodology is to be in accordance with a specified standard. The selection of seats to be assessed will depend on the equipment supported and the compartment in which it is situated.

5.6.2 Minor seats should be assessed to ensure that equipment remains captive. Detail design requirements such as minimum thickness, alignment, and free edge support can be specified to improve shock performance. In the absence of information, minor seats can be considered as those with equipment mass below 100 kg.

5.6.3 Seats which are not classed as minor are to be assessed for shock loads using acceleration values appropriate to the region of the ship in which the equipment is installed. Large items of equipment where the seat is integrated into the ship's structure will normally require a finite element analysis to assess the strength of the seat. Where these seats are adjacent to the hull or an integrated tank, the fluid structure interaction may need to be modelled. *See Vol 1, Pt 4, Ch 2, 5.4 Local strength assessment*.

5.6.4 The shock accelerations are to be specified by the Owner. In general, accelerations will be specified for the following regions of the ship:

(a) within 2,0 m of the wetted hull;
(b) main transverse bulkheads and decks below the strength deck;
(c) above strength deck and superstructures.

Shock accelerations can be scaled using a factor for different equipment based on its category of use.

5.6.5 For each equipment seat to be assessed, a report is to be provided containing the following information:

(a) equipment mass and centre of gravity;

(b) location in vessel;
(c) mounting system;
(d) spatial clearances around the mounted equipment;
(e) captivity requirements;
(f) relevant excitation frequencies from mounted equipment in the case of reciprocating or rotational machinery;
(g) calculations demonstrating maximum stress and displacement, under vertical acceleration, vertical deceleration and athwartships accelerations. For non-linear analyses, strain rates are to be provided;
(h) equipment alignment requirements, as appropriate.

5.6.6 As a minimum, the following seat load cases are to be assessed:

(a) bolts; pull through, tensile, shear and bearing strength;
(b) seat flange; flange bending and top plate weld area;
(c) seat web; buckling and overturning;
(d) deck; seat weld area if less than flange.

5.6.7 Stress and strain are to be assessed against criteria appropriate for the seat material and loading rate. The first fundamental mode of vibration of the seat including equipment is to be greater than 10 times the shock mount rated natural frequency to provide a sufficiently rigid base for the shock mount. In the absence of specific information, for steel, the following data may be used:

	Tension	Bending	Shear
Plastic deformation of seats	1,3 σ_{ps}	1,3 σ_{ps}	1,0 σ_{ps}
Long loading times ≥0,5 ms (elastic deformation only)	1,0 σ_{ps}	1,0 σ_{ps}	0,8 σ_{ps}
Short loading times <0,5 ms (elastic deformation only)	1,2 σ_{ps}	1,5 σ_{ps}	0,9 σ_{ps}

where

σ_{ps} = static 0,1% proof stress

The values in this Table are applicable to mild and high tensile steel grades up to a yield strength of 400MPa.

5.7 Shock mounts

5.7.1 All shock mounts are to be of an approved type. Approval is to be undertaken by organisations approved by the Naval Administration. Approval documentation should contain the following information in accordance with NATO document ANEP63:

(a) nature and application of the mount, including generic type, application, load range, shock displacement, environmental constraints and frequency range;
(b) description of the mount assembly, including the complete assembly, the mount and the associated components;
(c) details of the mount standard assembly and installation;
(d) physical size, mass and dimensions;
(e) performance data as listed in *Table 2.5.1 Shock mount characterisation*;
(f) details of the mount testing process, including method of force generation, number of mounts used/shots used, mount supplier, validation, mount permanent deflection, details of test facility and date of testing;
(g) mount specific protection, installation, inspection and maintenance requirements;
(h) any applicable historic data, i.e. changes to the mount details over time. For example, changes of material, etc.

Table 2.5.1 Shock mount characterisation

Mount size number			1
Nominal load		kg	
Static stiffness	Vertical *V* Horizontal H_A Horizontal H_R	N/m N/m N/m	
Dynamic stiffness	Vertical *V* Horizontal H_A Horizontal H_R	N/m N/m N/m	
% of critical damping			
Vertical static displacement at nominal load		mm	
Natural frequencies	Vertical *V* Horizontal H_A Horizontal H_R	Hz Hz Hz	
Dynamic magnification at resonance		–	
Shock displacement capacity	Vertical *V* Horizontal H_A Horizontal H_R	mm mm mm	
Maximum transmitted acceleration at nominal load	Vertical *V* Horizontal H_A Horizontal H_R	m/s^2 m/s^2 m/s^2	
Range of validity of mount surface/best fit governing equation (where applicable) relative to unloaded condition		±mm	
Required support stiffness		N/m	
Required support strength		N	

5.8 Design guidance for hull valves, piping and seals

5.8.1 Hull valves below the waterline are to be of an approved type. Approval is to be undertaken by organisations approved by the Naval Administration. Approval documentation should contain the following:

(a) details of the valve body, main components and securing arrangement to the hull, including bolt material grade and tightening torque;
(b) details of the valve testing process, including method of force generation, number of tests, validation, details of test facility and date of testing.

5.8.2 Only materials with sufficient ductility to avoid fracture under shock conditions are to be used. Materials should be able to withstand high stresses for very short periods without exhibiting brittleness. Valve bodies are not to be made from materials with an elongation of less than 10 per cent. There should be adequate material in way of the valve seat to prevent distortion.

5.8.3 In general, the valve body should be as symmetrical as possible with no rapid changes in section; web stiffeners should not be incorporated. Spindles should be as short as possible. Square threads or sharp thread run-outs are to be avoided. Handwheels should be as light and small as possible.

5.8.4 The weight of the actuator is to be considered in the design of the valve and its connection to the hull. The actuator can form a considerable proportion of the overall weight of the valve.

5.8.5 Consideration should be given to the attached piping and its capacity to withstand shock:

(a) Detachable pipe connections should be kept to the minimum necessary for installation and maintenance requirements;
(b) Flanged and welded connections are to be used adjacent to the hull valve. Adjacent piping is to be designed to allow the valve and hull to flex under shock with limited restraint;
(c) Where necessary, piping shall be supported with shock resistant mounts at a sufficient number of locations commensurate with the design shock level. The selection of shock mounts should consider displacement capability, *see Vol 1, Pt 4, Ch 2, 5.7 Shock mounts*. The response of the piping relative to equipment should be considered. Sufficient space between equipment and piping should be provided to ensure they do not contact each other in a shock scenario;
(d) The routing of piping should be developed to minimise the number and size of penetrations through bulkheads, *see Vol 1, Pt 4, Ch 2, 5.8 Design guidance for hull valves, piping and seals 5.8.11*;
(e) The consequences of leakage from piping and fittings should be investigated;
(f) Brackets should not be welded direct to steel piping;
(g) Adequate division of vital piping systems to isolate damage should be considered;
(h) The shock resistance of flanged connections should consider bolt preload, anti-rotational locking devices where appropriate and performance of gaskets.

5.8.6 The sealing arrangement between the valve and the hull insert is to be suitable for shock loading and able to accommodate elongation of the securing studs.

5.8.7 Hull valve designs can be approved by the following methods:

(a) physical testing;
(b) semi-empirical methods;
(c) direct calculation.

5.8.8 Physical shock testing may be used to assess the valve. Physical testing is to take account of the attachment to the hull and possible combinations of hull scantlings, stiffener spacing, materials, etc.

5.8.9 Recognised semi-empirical methods may be used to assess the valve.

5.8.10 Validated numerical methods may be used to assess the valve. Where used, they are to take account of the following criteria:

(a) asymmetry in the valve and piping assembly;
(b) dimensions of the hull insert/pad;
(c) use of sea tube between the valve and hull insert;
(d) hull scantlings and stiffener/frame spacing;
(e) plasticity in the hull and valve assembly;
(f) the effective mass of the valve, actuator and piping;
(g) the valve to hull securing arrangement, taking into account fit and pre-stress effects;
(h) dynamic properties of materials;
(i) the effect of any surrounding equipment or masses.

Sea tubes of unusual material, GRE for example, or unusual configuration are to be assessed by physical shock testing and not assessed by numerical simulation.

5.8.11 The potential for leakage from seals/glands under shock loading, and the consequences of leakage, are to be considered. The shock resistance of vital seals/glands, including stern-tube seals, is to be validated by shock qualification testing. The sealing efficiency of stern-tube seals should not be compromised by the anticipated axial, radial and angular shaft movements commensurate with the design shock level.

■ *Section 6* Whipping

6.1 General

6.1.1 The effects of a non-contact underwater explosion are described in *Vol 1, Pt 4, Ch 2, 5 Underwater explosion (shock)*. Whilst the initial shock wave described in that section initiates whipping to some degree it is the pulsation of the bubble which leads to the majority of damage to the hull. The initial shock wave causes local hull damage and shock damage to the vessels equipment. In the strain history shown in *Figure 2.6.1 Deck strains from hull whipping* the initial shock wave can be seen to be not just the free response of an elastic system to an impulse as the amplitude continues to increase. There is a typical second kick to the system which stems from the first bubble pulse and which increases the response for several more cycles.

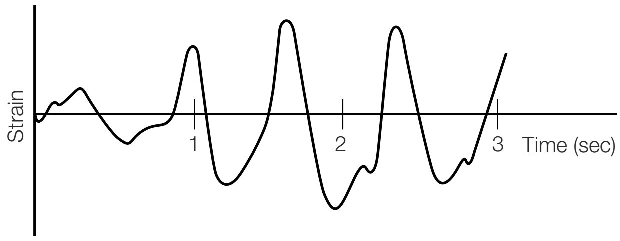


Figure 2.6.1 Deck strains from hull whipping

6.1.2 The nature and behaviour of the gas bubble are dependent upon the warhead charge size, the explosive composition, the detonation depth and the influence of boundaries such as the sea bed.

6.1.3 The maximum radius of the bubble at the end of the first expansion phase is given by:

$$R_{\mathrm{bub}} = 3{,}417\left(\frac{\mathrm{W}}{\mathrm{H} + 10}\right)^{\frac{1}{3}} \mathrm{m}$$

where

W = bare charge equivalent weight of TNT, in kg

H = depth of the charge at the time of detonation, in metres.

6.1.4 The period of duration of the first bubble pulse is given by:

$$t_{\mathrm{bub}} = 2{,}108 \frac{W^{1/3}}{(H + 10)^{5/6}} \text{ sec}$$

where

W and *H* are defined in *Vol 1, Pt 4, Ch 2, 6.1 General 6.1.3*.

6.1.5 Even a relatively modest warhead charge size can produce a bubble which displaces a large mass of water in a very short time frame. The momentum associated with this rapid incompressible flow of a sizeable volume of water constitutes a major loading mechanism for any structure within its sphere of influence.

6.1.6 The effect on the hull is a large amplitude vertical bending and vibration. This first introduces high shear forces at the quarter points which may cause shear wrinkling, this damage will probably not be catastrophic and the hull will go on to develop

high compressive forces in the keel. These may cause buckling especially as the bottom structure may already be damaged from the initial shock wave. For extreme cases whipping may lead to the 'back breaking' and total loss of the ship.

6.1.7 An estimate of the hull natural frequency for steel ships is given by:

$$f_{s1} = \frac{215}{L_{OA}} \text{HZ}$$

where

L_{OA} = the overall length of the ship, in metres.

6.1.8 The risk of a whipping response from a particular threat can be determined using the approximation for the natural frequency and the bubble characteristics of *Vol 1, Pt 4, Ch 2, 6.1 General 6.1.4*.

6.1.9 If the threat is closer to the hull than $2R_{bub}$ then the bubble loading is to be specially considered.

6.2 Threat level determination

6.2.1 The level to which a ship will be expected to survive an attack scenario that excites hull whipping is to be specified by the Owner and will remain confidential to LR.

6.2.2 The whipping threat level may be defined for a range of warheads detonating at a given stand off distance and longitudinal (axial) location. The probability of weapon hit locations can be determined from threat analyses which can be used to select the appropriate charge locations for the assessment.

6.2.3 It is also possible to undertake a parametric study to establish the detonation location which will lead to the worst case loading scenario. In this case, all possible hit locations that will induce whipping are assessed and the worst case induced bending moments are compared with an appropriate acceptance criteria. Contours from the keel of maximum threat size to induce failure can also be determined.

6.2.4 Where a shock threat is also being assessed for whipping effects, the warhead stand off distance from the keel is set to be the same as that which induces the prescribed severity of shock. A series of axial locations are assessed to establish the worst case excitation which is compared to the appropriate acceptance criteria.

6.2.5 The non-dimensional measure of whipping severity, commonly referred to as Whipping Factor, is simply the ratio of maximum induced hull girder bending moment at a section to the critical bending moment for that section. Each threat location assessed will generate a whipping factor which can be assigned to that particular location. In this way a series of iso-Whipping Factor contours can be mapped in the fluid beneath the keel for a particular threat weapon. These contours define hit volume boundaries within which that particular weapon will induce a known level of whipping response.

6.3 Notation assessment levels and methodology

6.3.1 Ships for which a whipping assessment is performed will be eligible for a **WH1, WH2** or **WH3** notation as defined in *Vol 1, Pt 4, Ch 2, 6.3 Notation assessment levels and methodology 6.3.4*

6.3.2 There are two types of assessment to determine the whipping response of the hull girder.

- Simple 2D beam model.
- Advanced 3D beam model.

6.3.3 For most ships a simple analysis will be sufficient to determine the whipping capability of the hull girder. An advanced analysis will be required when:

- more detailed information is required on areas of a ship which have been shown by simple analysis to be deficient under whipping loads, for example where there are large structural discontinuities variations;
- the ship design cannot be idealised as a 2D beam, for example when it has an unusual structural configuration or has low frequency modes of vibration in additional to its vertical flexural modes;
- there is a requirement to predict the extent of plastic deformation in a section;
- the whipping threats are assessed in a shallow water environment.

6.3.4 A **WH1** analysis method uses a 2D beam representation and a failure level criterion based on the bending moment to induce material yield.

6.3.5 A **WH2** method of analysis uses a 2D beam representation and a failure level criterion based on the section ultimate bending moments. This will require assessment using ultimate strength calculations at each of the discrete sections of the hull girder beam model.

6.3.6 A **WH3** method of analysis uses a 3D definition of a section of the hull girder and geometric and material failure criteria implicit in the chosen finite element code.

6.3.7 In each case, it is to be demonstrated that the hull section remains below the defined failure limits for all threat scenarios.

6.3.8 For certain ship types such as minesweepers, it will be necessary to carry out several levels of analysis. An elastic analysis is required for threat levels which are expected to be survived on a regular basis. An elasto-plastic analysis at a higher threat level for which the ship is expected to survive.

6.4 Simple 2D beam model

6.4.1 The modelling of ship interaction with explosion bubbles conveniently breaks down into a set of distinct sub-models.

6.4.2 The hull girder model is usually subdivided into at least twenty equal sections, each of which is assumed to form a ‘Timoshenko’ beam element. Since the stiffness and mass distributions may vary considerably along the length of a ship, a lumped mass/weightless beam representation is appropriate rather than a consistent mass model. The effect of shear deflection is to be included in the model.

6.4.3 The hull hydrodynamics may be modelled using standard strip theory to represent the effect of the inertia of surrounding water. At any lumped mass representing the hull girder, the added mass of water may be assumed using ‘Lewis’ forms coefficients. The added mass correction can be assumed to be constant for each mode of vibration.

6.4.4 For the bubble hydrodynamics it is assumed that the flow around the explosion bubble is inviscid and incompressible, that gaseous products obey ideal gas law, and that the bubble itself remains spherical. As a first approximation it may also be assumed that the bubble remains stationary but in general the migration is significant and should be considered. It is also assumed that the bubble motion is not modified by the presence of either the ship or the water surface. The loading model is to account for the dissipation of shock wave energy at the outset of detonation, generally achieved by using a modified initial radius for the bubble calculation.

6.4.5 The interaction hydrodynamics may also be assumed to be incompressible and inviscid consistent with the bubble hydrodynamics. The bubble radial flow may be resolved at the ship axis (the intersection line of the waterplane and the vertical centreline plane) at each lumped mass, into three components. Normally only the vertical z and athwartships y components need be considered as the bubble is assumed to be some distance from the ship. It may also be assumed that at each lumped mass, the transverse velocity around the whole section will be uniform in magnitude and direction.

6.4.6 The force acting on a strip is to account for this motion, plus the uniform pressure gradient assumed in the fluid which induces a buoyancy force proportional to the displaced volume of water. Wave generation and Bernoulli pressure effects may be neglected but the accelerations should account for the free surface reflection of the bubble.

6.4.7 Several assessment codes are available and calculation should be performed by a competent and experienced body with relevant experience and using recognised codes.

6.5 Advanced assessment

6.5.1 Advanced whipping assessments will normally be performed using a hybrid 3D/2D structural model for computational efficiency. However, care is to be exercised in the coupling of the 2D beam elements to the 3D section to ensure that this artificial boundary condition does not adversely influence the analysis. As an alternative, the ship may be defined as a full 3D shell model. In which case, it may be possible to invoke symmetry to reduce the problem size and reduce the computational burden.

6.5.2 More than one option exists for modelling the fluid domain. It may be modelled using a boundary element approach and coupled to the structural domain using a Doubly Asymptotic Approximation. Alternatively, a computationally intensive volume fluid element approach employing an Eulerian code may be used. This fluid domain model would have to be coupled to the Lagrangian structural domain through a general or arbitrary coupling scheme. The detonation process and the bubble development would be physically modelled in this approach. A combined approach would entail modelling an island of fluid around the ship, truncated by a boundary element surface on which a bubble loading model would be applied.

6.5.3 For surface ship problems, whichever solution strategy is adopted, the fluid solver must be able to cope with the proximity of the bubble to the free surface and where appropriate reflections from the sea bed. Analysis is to be undertaken by a

competent and experienced body using recognised techniques and with the relevant expertise necessary to establish the correct interface strategy between structural and fluid element meshes.

■ *Section 7* Residual strength

7.1 General

7.1.1 This Section details the determination of the threat levels and methodology to be adopted in the attainment of an **RSA1**, **RSA2** or **RSA3** notation.

7.2 Threat level determination

7.2.1 The level to which a ship will be expected to structurally survive an attack scenario that results in weapon damage is to be specified by the Owner and will remain confidential to LR.

7.2.2 The threat level may be defined for a range of warheads detonating at given internal positions or UNDEX stand off distances with defined longitudinal locations. The probability of weapon hit locations can be determined from threat analyses which can be used to select the appropriate charge locations for the assessment.

7.2.3 Generally, fragmentation scenarios are not included in residual strength assessments since the damage is usually localised. However, any significant structural damage resulting from fragmentation (as determined in *Vol 1, Pt 4, Ch 2, 4 Fragmentation protection*) must be considered. Similarly, any damage from an external blast threat weapon must also bep included (*Vol 1, Pt 4, Ch 2, 2 External blast*). In addition, residual strength calculations must be used in conjunction with level 2 whipping analysis (*Vol 1, Pt 4, Ch 2, 6 Whipping*).

7.2.4 Where the **STAB** notation is assigned, the damage scenarios included in the residual strength assessment are to include grounding/raking and collision damages which are consistent with the compartment damage criteria specified by the subdivision and stability standard, *see Vol 3, Pt 1, Ch 6, 1 General*.

7.3 Notation assessment levels and methodology

7.3.1 Ships for which a residual strength assessment is carried out will be eligible for a **RSA1, RSA2** or **RSA3** notation as defined in *Vol 1, Pt 4, Ch 2, 7.3 Notation assessment levels and methodology 7.3.6*.

7.3.2 The assessment of the residual strength capability of a ship is to be performed as defined in *Vol 1, Pt 6, Ch 4, 4 Residual Strength Assessment, RSA*.

7.3.3 There are three methods of assessment that may be used to determine the damaged residual strength of the hull girder.

- Simple 2D cross-section elastic model.
- 2D ultimate strength model.
- Advanced 3D Finite Element Methods.

7.3.4 In the case of a mine warfare ship or NS3 ships, a 2D elastic analysis will normally be sufficient. For most other naval ships, a 2D ultimate strength analysis would normally be required to determine the damaged residual strength at a particular frame location along the hull girder.

7.3.5 An advanced 3D analysis incorporating initial deformations and residual stresses will be required when:

- More detailed information is required throughout one or more compartments along the length of the ship which have been shown by the more simplified 2D ultimate strength analysis to be inadequate. This may be necessary, for example, where there are large structural discontinuities in hull girder strength.
- The ship design cannot be reduced to a 2D beam or ultimate strength description, for example, when it has an unusual structural configuration.

7.3.6 A **RSA1** analysis method uses a 2D elastic cross-section representation and a failure level criterion based on the calculated bending moment being greater than both the design hogging and sagging bending moments at the sections considered to be most critical.

7.3.7 A **RSA2** method of analysis uses a 2D ultimate strength beam representation and a failure level criterion based on the section ultimate bending moments being satisfactory compared to the design bending moments in both hogging and sagging. This will require assessment using ultimate strength calculations at no less than three damaged positions along the length of the hull.

7.3.8 A **RSA3** method of analysis uses a 3D definition of a section of the hull girder and relies on geometric and material failure criteria implicit in the chosen finite element code. It could also include coupled Euler-Lagrange formulations to specifically account for internal and external blast effects, UNDEX shock and whipping.

7.3.9 In each case, it is to be demonstrated that the hull girder remains below the defined design hogging and sagging design bending moment failure limits for all prescribed threat scenarios.

7.3.10 For certain ship types, such as minesweepers, it will be necessary to carry out several levels of analysis. An elastic analysis should be carried out for threat levels which are expected to be survived on a regular basis and geometric and material nonlinear analysis at higher threat levels for which the ship is expected to survive.

7.4 Definition of damage

7.4.1 The damage radius is a measure of the extent of the damage caused by specific above water attack scenarios. This is shown diagrammatically in *Figure 2.7.1 Determination of damaged structure*, where the assumption of a detonation mid-compartment is shown and the extent of damage is indicated by the extent of the damage radii. Assumptions about position and extent of damage radii are dependent on warhead characteristics. In general, the radii is to be vertically positioned such that it removes the maximum amount of material or has the greatest effect on the sectional inertia.

7.4.2 The damage radii can be determined from:

$$r = f_z W^{1/3} \text{ m}$$

where

f_z = scaled distance dependent on ship type

W = equivalent weight of TNT, in kg.

7.4.3 Once a damage radius has been determined, the simplest method of accommodating damage is to remove all structure within and touching the damage radii from the residual strength calculation.

7.4.4 For underwater shock (UNDEX), hull plating failure can be derived from angle hull shock factor, as defined in *Figure 2.7.2 Angle shock factor*, exceeding appropriate hull lethality levels. The angled shock factor may be determined from:

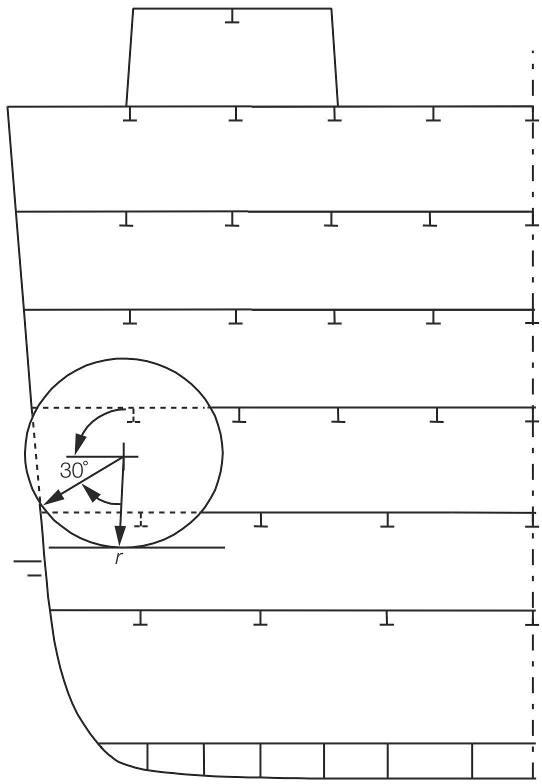
$$SF = \frac{W^{0,5}}{R} f(\theta)$$

where

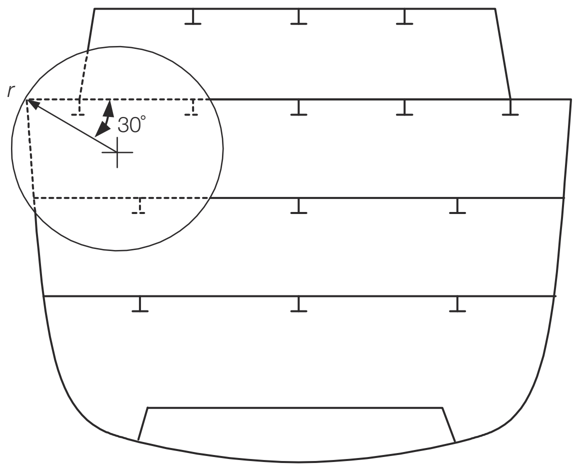
W = equivalent charge weight of TNT, in kg

R = distance from charge, in metres

$f(\theta)$ = threat angle function, *see Figure 2.7.2 Angle shock factor*.



NS1 ship



NS2 and **NS3** ship

Figure 2.7.1 Determination of damaged structure

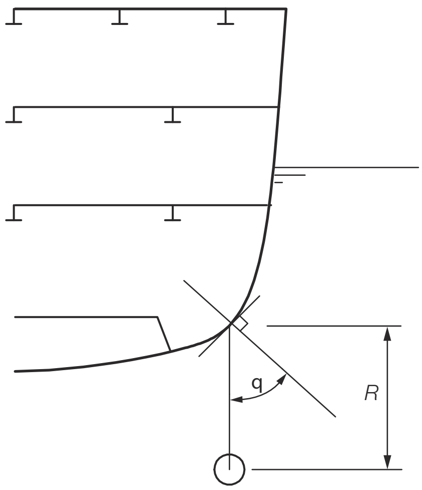


Figure 2.7.2 Angle shock factor

7.4.5 Special consideration will be given to the effects of damage to box type strengthening structure, armour plating, high yield strength materials, double skin hulls and blast strengthened bulkheads.

7.4.6 Generic damage can be generated using pseudo-random hit probability algorithms and repeated application of such algorithms can be used to represent successive weapon hits. Specific damage is difficult to quantify but can be estimated by using damage radii techniques for above water structure and by assuming critical shock factor levels for below water structure.

■ *Section 8* Strengthening requirements for beach landing operations

8.1 General

8.1.1 These requirements are in addition to those of *Vol 1, Pt 6, Ch 3 Scantling Determination* for bottom shell structure. They need only be applied to those areas of the hull at risk from grounding during beach landing operations. These areas are to be agreed with LR at an early stage in the plan approval process. A distinction is made between those areas likely to see impact loads on beaching and those where contact due to grounding will occur after the initial beaching.

8.1.2 The Rules assume that the ships will be brought into shallow water and up to the beach in a controlled manner and that procedures are in place and on board for the operation of these ships. The beach is assumed to be free of rocks of substantially greater projection than the depth of the rubbing strake.

8.1.3 Depending on the operational profile of the ship the minimum bow height given in *Vol 1, Pt 3, Ch 2, 5.3 Minimum bow height and extent of forecastle* will be specially considered.

8.1.4 Loading ramps are to be in accordance with the requirements of *Vol 1, Pt 4, Ch 3, 5 Movable decks, lifts, internal and external ramps*.

8.1.5 Due regard is to be given to forces imposed on the ship and loading ramps by ship motions in shallow water both by impact from surf, the beach, and vehicles used to manoeuvre ships on the beach.

8.2 Minimum plate thickness

8.2.1 For areas subject to impact and grounding the thickness determined from *Vol 1, Pt 6, Ch 3 Scantling Determination* is to be increased by 20 per cent and is in no case to be taken as less than 7 mm.

8.2.2 For operation in Arctic and Antarctic conditions the material grades are to be in accordance with the requirements of *Vol 1, Pt 6, Ch 6, 2 Materials* Material Class II.

8.3 Bottom stiffening

8.3.1 Secondary stiffening is to be designed in accordance with the requirements of *Vol 1, Pt 6, Ch 3 Scantling Determination* with the modulus increased by 20 per cent. For impact areas the spacing of stiffeners is not to be greater than 500 mm.

8.3.2 Primary structure is to be designed in accordance with the requirements of *Vol 1, Pt 6, Ch 3 Scantling Determination*. An additional load case with the forces imposed from global bending and grounding forces uniformly distributed over the bottom in contact with the beach is to be considered. In the absence of specific information, not more than 50 per cent of the bottom structure is to be assumed to be in contact with the beach. The primary structure is also to be capable of supporting the concentrated loads imposed by loading or unloading vehicles.

8.3.3 Primary and secondary structure is to be continuously welded throughout areas subject to grounding.

8.3.4 Lugged connections or fully welded collars of the type shown in *Figure 2.8.1 Collar arrangement* are to be used. Alternative equivalent arrangements will be individually considered.

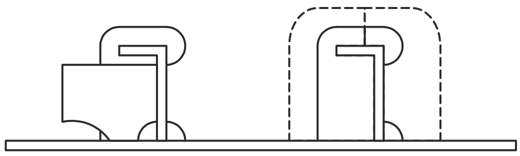


Figure 2.8.1 Collar arrangement

8.3.5 Transverse floors are not to be spaced more than 1,25 m for transversely framed structure or 1,85 m for longitudinal framed structure.

8.3.6 One side girder each side of the centreline is to be fitted in addition to the requirements of *Vol 1, Pt 3, Ch 2, 3.5 Single bottom structure* or *Vol 1, Pt 3, Ch 2, 3.6 Double bottom structure*.

8.3.7 Transverse floors and girders are to be suitably stiffened with web stiffeners spaced not more than 1,25 m apart.

8.4 Global strength

8.4.1 For ships with $L_R > 50$ m grounding conditions in addition to the loading conditions of *Vol 1, Pt 6, Ch 4 Hull Girder Strength* are to be assessed. The number and type of loading conditions will be determined by the operational requirements of the ship. In some cases residual strength calculations will be required.

8.4.2 If $L_R > 50$ m and areas of the bottom shell within 0,3 to $0{,}5L_R$ are at risk from grounding the thickness of the bottom shell and longitudinal structure will be specially considered.

8.5 Rubbing strakes

8.5.1 Rubbing strakes or barwhales are to be fitted to the bottom shell. In longitudinally framed ships they are to be placed directly below longitudinals. Typical arrangements of rubbing strakes are shown in *Figure 2.8.2 Rubbing strakes*. Usually they consist of a steel frame welded to the hull supports with a bolted connection to softer material but rubbing strips can be constructed of solid steel sections. They are to be free of projections or other discontinuities which could lead to damage of the shell plating.

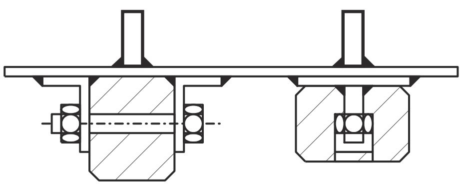


Figure 2.8.2 Rubbing strakes

8.5.2 It is recommended that rubbing strakes are not to be spread more than 1,5m apart. For rubbing strakes spaced greater than 1,5m the bottom structure is to be specially considered.

8.5.3 The rubbing strake housing both internally and externally is to be efficiently coated to prevent corrosion. Where different materials are used the materials are to be selected or insulated to ensure that there is no galvanic corrosion.

8.5.4 Rubbing strakes are to be continuously welded to the hull. Butts between sections of rubbing strake are to be butt welded together before being welded to the hull. Where this is not possible, ceramic rather than copper backing strips are to be used.

8.5.5 Rubbing strakes are to be of the same grade of steel as the shell plate to which they are attached.

8.5.6 The ends of rubbing strakes are to be tapered at an angle of not less than 1 in 3 with no discontinuities in the welding in this region. Where not supported by internal longitudinals, the ends of strakes are to be arranged to pass 30 to 50 mm over the end of transverse frames or floors.

8.5.7 Due consideration is to be given to the depth of the rubbing strakes with regard to the nature of the beach. In no case are they to be less than 100 mm projection.

■ *Section 9*
Military installation and operational loads

9.1 Weapon recoil, blast and efflux loads

9.1.1 Loads resulting from weapon launch may include recoil effects, blast and missile efflux pressures, and in general will be impulsive. These three types of load are estimated in different ways and will be covered in turn.

9.1.2 Gun and mortar recoil loads will generally be obtained from the manufacturer's documentation. If the natural frequency of the supporting structure is more than four times the firing rate and at least 50 per cent higher than the frequency derived from the time to maximum force, then a dynamic load factor of 1,6 may be used for a first estimate. If the gun is mounted immediately above an effective bulkhead then the structural resonant frequencies will be much higher and a dynamic load factor of 1,2 may be assumed. The stiffness of the supporting structure should be adequate for the loads imposed and in accordance with the manufacturer's recommendations.

9.1.3 The assessment of structure is to be made at the azimuth and elevation of the gun that produces the maximum demands on each component of the support structure. These will usually be ahead and abeam and at 0° and maximum elevation, although additional calculations should be made at the 45° positions vertically and horizontally against the resolved in-plane and normal elements of the load which occur simultaneously.

9.1.4 The load on the structure due to gun blast is in the form of a short-lived transient over-pressure; values of this over-pressure should be available in the manufacturer's documentation for the weapon as curves of pressure against distance from the gun muzzle. The pressure will act only for a time of the order of 10ms so the structure, with a much higher natural response period, is unable to react to the full over-pressure and it is sufficient to design to an equivalent static pressure using the dynamic load factors specified in *Vol 1, Pt 6, Ch 2, 5 Dynamic loading*. Guns with a high rate of fire, typically greater than 30 rounds per minute, may induce a forced vibration and will be specially considered.

9.1.5 Should blast pressure curves not be available then a spherical approximation to the equivalent static design pressure P_g can be found from the following equation for φ_m values in the range 80 mm to 120 mm

$$P_g = 2\,(1+\cos\theta)^2 \left(\frac{\varphi_m}{x}\right)^{1,5} \times 10^3 \text{ kN/m}^2$$

where

φ_m = the bore of the gun, in mm

x = the distance from the muzzle of a point at which the pressure is required, in mm

θ = the angle to the centre-line of the barrel.

As shown in *Figure 2.9.1 Gun blast geometry*

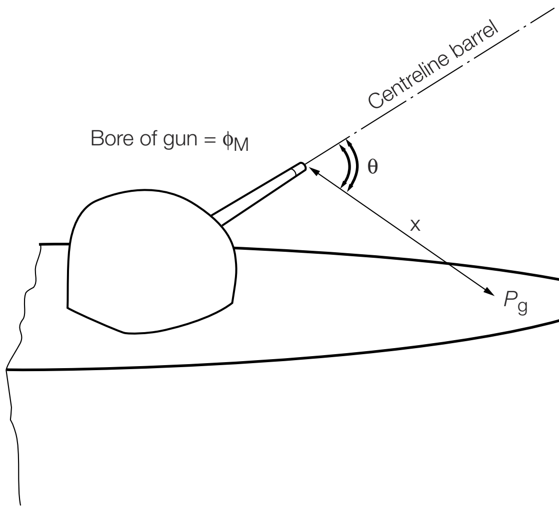


Figure 2.9.1 Gun blast geometry

9.1.6 Missile efflux blast loading can be predicted by considering the rate of change of momentum of the efflux where it strikes the structure under consideration. However, when calculating the equivalent design load allowance must also be made for the dynamic response of the structure. For practical purposes therefore it is sufficient to design for the thrust averaged over a cone of semi-angle *b* and the resultant equivalent static pressure P_m may be found from

$$P_m = f_{DLF}\left(\frac{T_m}{A}\right)\left(\frac{\sin\alpha}{\sin\alpha + \tan\beta \cos\alpha}\right) \text{ kN/m}^2$$

where

f_{DLF} = a dynamic load factor relating to variations in the efflux pressure and can be taken as 1,5

T_m = thrust, in kN

α = angle (25° < α < 90°) to the structure in degrees

A = projected area of cone in m^2

β = the efflux cone semi-angle in degrees and can be taken as 3°

As shown in *Figure 2.9.2 Missile thrust geometry*.

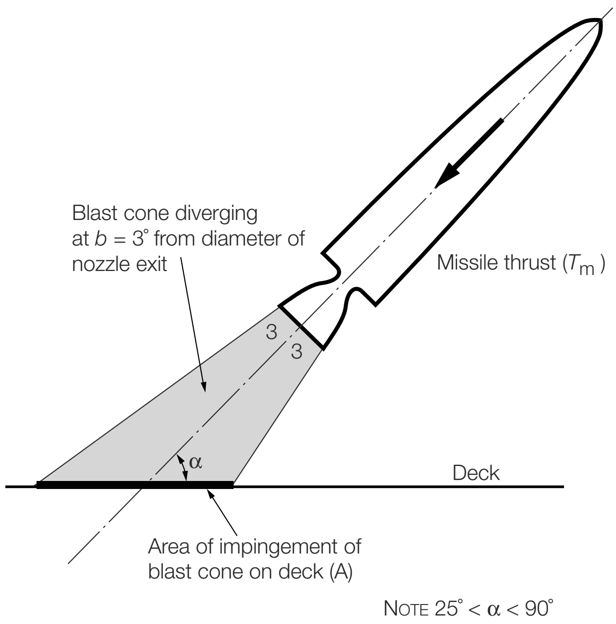


Figure 2.9.2 Missile thrust geometry

9.1.7 Missile efflux will generally be at high temperature and may contain particulates. Protection is to be provided for ship structure and equipment upon which the efflux may impinge during launch.

9.2 Replenishment at sea loads

9.2.1 The loads imposed on the ship's structure will depend on the operation of the vessel during RAS operation and what weight of stores is to be transferred.

9.2.2 Guidance on representative arrangements is presented in *Figure 2.9.3 Replenishment at sea loads*. It is the responsibility of the Owner to specify the design load values. The line of action of the forces is to be considered for all possible angles that might occur during replenishment operations.

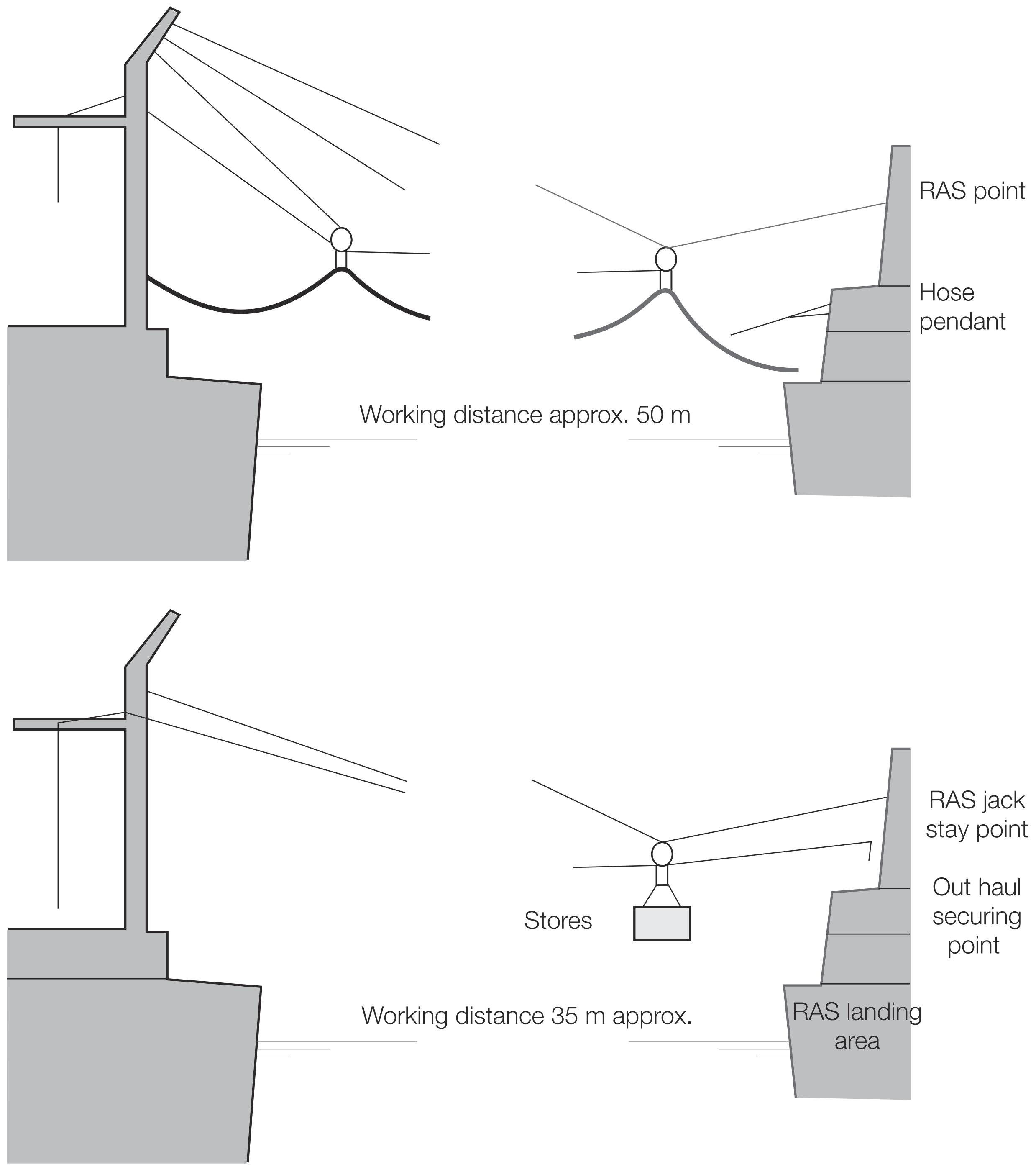


Figure 2.9.3 Replenishment at sea loads

9.2.3 In the absence of any specific information the RAS jackstay point is to be designed for 160 kN at 20^{o} either side of the vertical and 20^{o} either side of the horizontal. The outhaul securing point and hose pendent securing point are to be designed for 40 kN 20^{o} either side of the vertical and 0^{o} to 45^{o} below the horizontal.

9.2.4 The structure is to be designed such that the stress from RAS operations in no part of the structure exceeds 70 per cent of the yield stress of the material under test conditions and 35 per cent of the yield stress of the material under normal working conditions.

9.2.5 For structure supporting RAS equipment, materials are to be in accordance with *Table 6.2.1 Material classes and grades*.

9.2.6 Where tripods, gantries or masts are used for RAS operations the buckling strength of members in compression is to be specially considered.

9.2.7 A clear area is to be provided for RAS operations and the landing area for RAS operation is to be suitably strengthened for impact loading and concentrated equipment loads.

9.2.8 The design load used in the determination of scantlings for tanks used in RAS operation are to take due account of the maximum loads experienced in service. *See Vol 1, Pt 5, Ch 3, 5 Local design loads for decks and bulkheads*.

■ *Section 10* **Aircraft operations**

10.1 General

10.1.1 The landing area may be located on an appropriate area of the weather deck or on a platform specifically designed for this purpose and permanently connected to the ship structure. All ships operating aircraft are to comply with the requirements of this Section and will be assigned an **AIR** notation.

10.1.2 Attention is drawn to the requirements of National and other Authorities concerning the construction of helicopter landing platforms and the operation of helicopters as they affect the ship. Consideration should also be given to air flow over the landing area and the impingement of hot exhaust gases on equipment in the flight path.

10.1.3 Where the landing area forms part of a weather or erection deck, the scantlings are to be not less than those required for decks in the same position.

10.1.4 Equipment and vehicles using the landing area will also need to be assessed to identify the most onerous load in accordance with *Vol 1, Pt 5, Ch 3 Local Design Loads*.

10.1.5 Special consideration is to be given to the insulation standard if the space below the aircraft deck is a high fire-risk space.

10.1.6 These Rules assume that the aircraft are fitted with oil/gas dampers and pneumatic types, different under-carriage arrangements will be specially considered.

10.1.7 Suitable arrangements are to be made to minimise the risk of personnel sliding off the landing area. A non-slip surface is to be provided and is to cover the entire deck including any markings. Safety nets are to be provided in accordance with *Vol 1, Pt 3, Ch 4, 9.6 Safety nets*.

10.1.8 Structural fire protection, firefighting equipment and services are to be arranged on and around flight operations areas of the ship in accordance with the specified fire safety standard, *see Vol 1, Pt 1, Ch 2, 1.1 Framework of Classification 1.1.10*.

10.2 Definitions

10.2.1 OLEO load is defined as the load which will cause the damper and tyre combination to reach the end of their travel. OLEO loads should not generally be used to determine loads from the undercarriage on the flight deck. OLEO loads do not always reflect the loads that can be imposed by an aircraft landing on a ship. Loads should be derived using the vertical velocities specified in *Table 2.10.3 Vertical velocity*. The ratios of OLEO loads may be used to determine the dynamic distribution of load from the undercarriage.

10.2.2 The all up weight (AUW) is the maximum that will be encountered for the specific application under consideration it includes the maximum weight of aircraft, personnel, fuel and payload:

- For helicopters the AUW is to be taken as the maximum weight of aircraft, personnel, fuel and payload at all times.
- For manoeuvring of fixed wing aircraft the AUW is to be taken as the maximum weight of aircraft, personnel, fuel and payload.
- For take off of fixed wing aircraft the fuel weight is to be the maximum less the fuel required to transit to the take off position.
- For landing of fixed wing aircraft the AUW is to be as above except that the fuel weight is to be the maximum less that consumed by the shortest possible flight.

10.3 Documentation

10.3.1 Plans are to be submitted showing the proposed scantlings and arrangements of the structure. The type, size and weight of aircraft to be used are also to be indicated.

10.3.2 Details of arrangements for securing the aircraft to the deck are to be submitted for approval.

10.3.3 A landing guide should be provided as part of the ship's documentation. This is to contain all the relevant design information on the aircraft for the ship, identification of landing parking and manoeuvring areas, tie down arrangements, weights and a summary of the design calculations. It is also to provide guidance on the suitability of the landing areas for other aircraft. The information is to be presented in a graphical form similar to that shown in *Figure 2.10.1 Landing diagrams*. Unrestricted landings are aircraft weights which can occur up to the design sea state. Restricted landing with weights higher than the design can occur but in a reduced sea state and are to be indicated on the diagram. Prohibited landings are aircraft weights that may not take place in any sea state. Different diagrams will be required for twin and single rotor helicopters and for aircraft as appropriate.

10.4 Flight deck arrangements

10.4.1 The landing area is to be sufficiently large to allow for the landing and manoeuvring of the aircraft, and is to be approached by a clear landing and take off sector complying in extent with any applicable regulations.

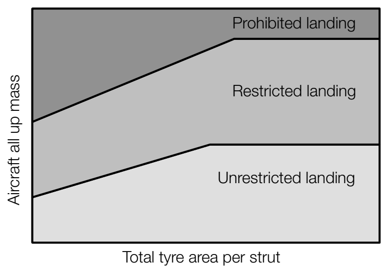


Figure 2.10.1 Landing diagrams

10.4.2 Normally, for maximum flexibility in helicopter operations, the landing area is to be taken as a square not less than 1,25 times the rotor diameter. Where the operation of helicopters is restricted to known helicopter types, the areas of deck structure to be assessed for the landing condition are to be taken as squares not less than two times the maximum wheel strut spacing. The squares are to be centred on all the normal landing points, at all specified landing orientations, for all helicopters. For fixed wing aircraft the area to be considered will be determined by the operational requirements of the vessel. The landing area is to be clearly identified.

10.4.3 The takeoff and landing area are generally to be free of projections above the level of the deck. Projections above 25 mm may only be permitted where allowed by the aircraft undercarriage design standard. Projections outside the landing and take off areas are to be kept to a minimum such that they do not hinder aircraft manoeuvring operations.

10.4.4 The structure is to be designed to accommodate the largest aircraft type which it is intended to use. It is advised that an allowance be made for future growth of the helicopter weight such that future operations are not restricted to lower sea states.

10.4.5 Engine uptake arrangements are to be sited such that exhaust gases cannot as far as practicable be drawn directly into aircraft engine intakes during aircraft take off or landing operations under anticipated operating conditions that include ship speed, ship motion and wind direction.

10.4.6 Arrangements are to be made for the drainage of the flight deck and other aircraft handling areas, including drainage of spilt fuel. The drainage arrangements are to be made of steel and are to lead away from enclosed spaces and directly overboard so as to avoid entrapment of burning fuel should an accident occur.

10.4.7 Flight decks are to be bounded by a coaming of approximately 50mm which is to be an integral part of the drainage system.

10.4.8 Flight decks are to have at least two means of escape located as far away as practicable from each other.

10.5 Loading

10.5.1 The load cases to be applied to all parts of the structure are defined in *Table 2.10.6 Design load cases for primary and secondary deck stiffening and supporting structure*. in which:

f = 1,15 for landing decks over magazines or permanently manned spaces, e.g deckhouses, bridges, control rooms, etc.

= 1,0 elsewhere

λ = reaction factor for the aircraft considered .

W_{auw} = the maximum all up weight of the aircraft, in kN

W_{ty} = landing or static load, on the tyre print, in kN; with the centre of gravity in a position that causes the highest load. In the absence of specific aircraft manufacturers' information on the static or dynamic distribution of load, W_{ty} is to be taken as W_{auw} divided equally between the two main undercarriages ignoring the nose or tail wheel. For helicopters with twin main rotors W_{ty} is to be taken as W_{auw} distributed between all main undercarriages in accordance with the static load distribution.

10.5.2 The reaction factor, λ, may be determined from *Table 2.10.1 Landing reaction factor* where manufacturers' information is not available. Otherwise the information in *Vol 1, Pt 4, Ch 2, 10.6 Determination of λ for fixed wing aircraft* or *Vol 1, Pt 4, Ch 2, 10.7 Determination of λ for helicopters* as appropriate may be used to estimate λ.

Table 2.10.1 Landing reaction factor

Aircraft type	λ
Helicopters	2,5
VSTOL aircraft	3,5
Fixed wing aircraft	5
Note Reaction factors are derived from the average values for marinised versions of aircraft.	

10.5.3 The reaction factor for helicopters using recovery systems will be specially considered.

10.6 Determination of λ for fixed wing aircraft

10.6.1 The reaction factor can be calculated by simulation, testing or estimated from the following formulae:

$$\lambda = \frac{V^2_{\mathrm{L}}}{2g\left(\eta_{\mathrm{T}}\,\delta_{\mathrm{T}} + \eta_{\mathrm{S}}\,\delta_{\mathrm{s}}\right)}$$

where

λ = reaction factor

δS, δT = deflection of the shock absorber or tyre, in metres

V_L = vertical landing velocity including ship motions, in m/s

ηT = efficiency of the tyre typically assumed to be 0,47

ηS = efficiency of the shock absorber, *see Table 2.10.2 Shock absorber efficiency*.

Table 2.10.2 Shock absorber efficiency

	Steel spring	Rubber	Air	Liquid spring	OLEO
η	0,5	0,6	0,48	0,76	0,8

10.6.2 The vertical velocity is the maximum landing velocity derived from trials or simulation and is to include the effects of ship motion. In no case is it to be taken less than 6 m/s. If landing operations are to be carried out in sea states greater than six then the minimum vertical velocity will be further considered.

10.7 Determination of λ for helicopters

10.7.1 The reaction factor can be calculated by simulation, testing or estimated from the following formulae:

$$\lambda = \frac{V_{\mathrm{L}}^2}{2g\left(\eta_{\mathrm{T}}\,\delta_{\mathrm{T}} + \eta_{\mathrm{S}}\,\delta_{\mathrm{S}}\right)} + \frac{\left(1 - f_{\mathrm{L}}\right)\left(\delta_{\mathrm{T}} + \delta_{\mathrm{S}}\right)}{\eta_T\,\delta_{\mathrm{T}} + \eta_{\mathrm{S}}\,\delta_{\mathrm{S}}}$$

where

λ, δ_S, δ_T, V_L, η_T, η_S are defined in *Vol 1, Pt 4, Ch 2, 10.6 Determination of λ for fixed wing aircraft*

f_L = the percentage of lift carried by the rotors at the time of landing typically 66 per cent.

10.7.2 The vertical velocity is the maximum landing velocity derived from ship trials or simulation and is to include the effects of ship motion. In no case is it to be taken less than 3,72 m/s. If landing operations are to be carried out in sea states greater than six then the minimum vertical velocity will be further considered.

10.7.3 For ships where helicopter operations are restricted to sea states lower than six the vertical velocities defined in *Table 2.10.3 Vertical velocity* can be used.

Table 2.10.3 Vertical velocity

Sea state	Vertical velocity
6	3,72
5	3,35
4	2,97
3	2,60
2	2,23

10.7.4 Using a vertical velocity lower than the design given in this section, for example a land based helicopter, will result in higher probabilities of exceedence. The derivation of vertical velocity is such that it includes the effects of ship motions and pilot action and is independent of the design vertical velocity of the undercarriage.

10.7.5 Information on the probability of encountering a particular sea state for a sea area can be found in *Vol 1, Pt 5, Ch 2, 2 Wave environment*.

10.7.6 For helicopters with skids, determination of the reaction factor will be specially considered.

10.8 Deck plating design

10.8.1 The deck plate thickness, t_p, within the landing area is to be not less than:

$$t_p = \frac{\alpha\,s}{1000\sqrt{k_s}} - t_c \text{ mm}$$

where

α = thickness coefficient obtained from *Figure 3.2.1 Tyre print chart* using a value of β given by

β = tyre print coefficient used in *Figure 3.2.1 Tyre print chart*

$$\beta = \log_{10}\left(\frac{0,6F_{\mathrm{typ}}\,\varphi_1\,\varphi_2\,\varphi_3\,\gamma\,k_{\mathrm{s}}^2}{9,81s^2} \times 10^7\right)$$

k_s = higher tensile steel factor defined in *Vol 1, Pt 6, Ch 5 Structural Design Factors*

where

s = stiffener spacing, in mm

F_{typ} = tyre force, in kN from *Table 2.10.6 Design load cases for primary and secondary deck stiffening and supporting structure*

λ = reaction factor for the aircraft considered, *see Vol 1, Pt 4, Ch 2, 10.5 Loading*

γ = a location factor given in *Table 2.10.4 Location factor, γ*

φ_1, φ_2, φ_3 = are patch load correction factors determined from *Table 2.10.5 Patch load corrections φ_1, φ_2, φ_3*

t_c = permanent set correction in mm, *see Vol 1, Pt 4, Ch 2, 10.8 Deck plating design 10.8.2*

a, s = the panel dimensions in mm, *see Figure 2.10.2 Tyre patch dimensions*

u, v = the patch dimensions in mm, *see Figure 2.10.2 Tyre patch dimensions*.

Table 2.10.4 Location factor, γ

Location	Y
On decks forming part of the hull girder	
(a) within 0,4L_R amidships	1,18
(b) at the FP or AP	1,0
	Values for intermediate locations are to be determined by interpolation
Elsewhere	1,0

Table 2.10.5 Patch load corrections φ_1, φ_2, φ_3

Factor	Condition
$\varphi_1 = \dfrac{2v_1 + 1,1s}{u_1 + 1,1s}$	$v_1 = v$, but $\leq s$ $u_1 = u$, but $\leq a$
φ_2 = 1,0 $= \dfrac{1}{1,3 - 0,3(a-u)/s}$ = 0,77a/u	for $u \leq (a - s)$ for $a \geq u > (a - s)$ for $u > a$
φ_3 = 1,0 = 0,6 (s/v) + 0,4 = 1,2 (s/v)	for $v < s$ for 1,5 > (v/s) > 1,0 for (v/s) ≥ 1,5

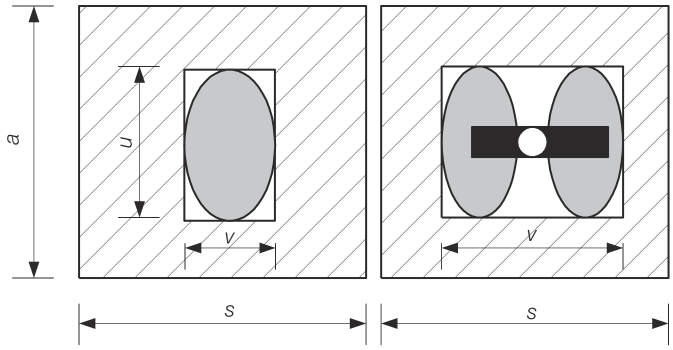


Figure 2.10.2 Tyre patch dimensions

10.8.2 The permanent deflection correction, t_{c}, is a plating thickness reduction which can be applied if aircraft manoeuvring take off and deck equipment operations allow some permanent set to occur

$$t_{c} = 0{,}001\, C\, s^{n} \text{ mm}$$

where

C = 0,00071 and n = 2,2 for moderate deformations

C = 0,0154 and n = 1,85 for large deformations.

10.8.3 Moderate deformations are defined as those that will restrict manual manoeuvring of the aircraft. They will typically be 1,5 times the deflection expected from normal ship construction.

10.8.4 Large deformations are defined as those that will restrict operations to aircraft landing only with no wheeled vehicle operations they will typically be 2,5 times the deflections expected from normal ship construction.

10.8.5 If permanent deformation of the landing area plating is to be allowed then the plating must also be assessed for normal operations with t_{c} = 0,0 mm.

10.8.6 The permanent deflection correction is not to be applied to landing areas within 0,3L_{R} to 0,7L_{R} and other areas where there are significant in-plane stresses in the plate. Also the correction is not to be applied to areas where deflections could cause operational restrictions, for example the use of forklift trucks or rolling take off.

10.8.7 The static tyre print dimensions at W_{auw} specified by the manufacturer are to be used for the calculation. Where these are unknown it may be assumed that the print area is 200 mm x 300 mm and this assumption is to be indicated on the submitted plan.

10.8.8 Twin wheels are to be combined to form a single patch as shown in *Figure 2.10.2 Tyre patch dimensions*

10.8.9 For helicopters fitted with landing gear consisting of skids, the print dimensions specified by the manufacturer are to be used. Where these are unknown it may be assumed that the print consists of a 300 mm line load at each end of each skid, when applying *Figure 3.2.1 Tyre print chart*

10.8.10 For decks fitted with sheathing greater than 25 mm a reduced plate thickness from that given in *Vol 1, Pt 4, Ch 2, 10.8 Deck plating design 10.8.1* may be specially considered.

10.8.11 For steel decks in frequent use and where no suitable protective sheathing or coating is used, it is recommended that the thickness of the plating is increased, *see Vol 1, Pt 6, Ch 6, 2.10 Corrosion margin*

10.9 Deck stiffening design

10.9.1 The aircraft deck stiffening is to be designed for the load cases given in *Table 2.10.6 Design load cases for primary and secondary deck stiffening and supporting structure* with the aircraft being positioned so as to produce the most severe loading condition for each structural member under consideration. All possible positions and orientations are to be considered that can occur during aircraft operations.

10.9.2 The minimum requirements for section modulus, inertia and web area of secondary stiffeners are to be in accordance with the requirements of *Table 3.2.3 Secondary stiffener requirements*, using the load cases defined in *Table 2.10.6 Design load cases for primary and secondary deck stiffening and supporting structure*

Table 2.10.6 Design load cases for primary and secondary deck stiffening and supporting structure

Condition	Loading					
		Stiffening			Support structure	
	Plate F_{typ} kN	P_{tyw} kN/m^2	Point loads F_{tys} kN	Self weight F_{tym} kN	Vertical kN	Horizontal kN
Emergency landing	$\lambda f W_{ty}$	0,2	$DLF \lambda f W_{ty}$	$(1 + a_z) W_s$	Self weight W_{pl} plus landing loads from all wheels	0,5 W_{auw} 0,5 W_{auw} + 0,5 W_{pl}
Normal landing	0,6 λW_{ty}	0,5	0,6 $DLF \lambda W_{ty}$	$(1 + a_z) W_s$		
Take off (fixed wing	2,65 W_{ty}	0,5	2,65 W_{ty}	$(1 + a_z) W_s$		
Manoeuvring internal	1,6 W_{ty}	—	1,6 W_{ty}	$(1 + a_z) W_s$		
Manoeuvring external	1,75 W_{ty}	0,5	1,75W_{ty}	$(1 + a_z) W_s$		
Parking internal	$(1 + 0{,}6a_z) W_{ty}$	—	$(1 + 0{,}6a_z) W_{ty}$	$(1 + a_z) W_s$		
Parking external	$1{,}1(1 + 0{,}6a_z) W_{ty}$	2	$1{,}1(1 + 0{,}6a_z) W_{ty}$	$(1 + a_z) W_s$		

W_{ty} W_{auw} and f as defined in *Vol 1, Pt 4, Ch 2, 10.5 Loading*
λ is defined in *Vol 1, Pt 4, Ch 2, 10.8 Deck plating design*

W_{pl} = structural weight of helicopter platform, in kN

W_s = structural weight of stiffener and supported structure, in kN

P_{tyw} = uniformly distributed vertical load over entire landing area, kN/m^2

DLF = Dynamic load factor
Fixed wing 1,35 for secondary stiffening, 1,5 for primary stiffening
Helicopters 1,2 for secondary stiffening, 1,5 for primary stiffening

a_z is defined in *Vol 1, Pt 5, Ch 3, 2 Motion response*

Note 1. For the design of the supporting structure for helicopter platforms applicable self weight and horizontal loads are to be added to the landing area loads.

Note 2. The helicopter is to be so positioned as to produce the most severe loading condition for each structural member under consideration.

Note 3. Stiffening members may have more than one point load acting at one time.

10.9.3 For primary stiffening, and where a grillage arrangement is adopted, it is recommended that direct calculation procedures are used to determine the scantling requirements in association with the limiting permissible stress criteria given in *Table 5.3.2 Allowable stress factors f 1* in Pt 6, Ch 5. The calculation is to be submitted for consideration.

10.9.4 Where continuous secondary stiffeners pass through the webs of primary members, they are to be fully collared or lugged in way. The shear stresses at the connections are to be in compliance with *Vol 1, Pt 6, Ch 5 Structural Design Factors*.

10.10 Parking and manoeuvring areas

10.10.1 For areas designed for parking and manoeuvring of aircraft the maximum take off weight of the aircraft is to be used with the maximum fuel and payload.

10.10.2 For areas where only manoeuvring occurs and parking is restricted to designated and clearly marked areas then the scantlings of structure are to be calculated in accordance with *Vol 1, Pt 4, Ch 2, 10.8 Deck plating design* and *Vol 1, Pt 4, Ch 2, 10.9 Deck stiffening design* using the manoeuvring and parking loads given in *Table 2.10.6 Design load cases for primary and secondary deck stiffening and supporting structure* as appropriate. If parking areas are not clearly marked then the parking loads in *Table 2.10.6 Design load cases for primary and secondary deck stiffening and supporting structure* are to be applied to all areas of aircraft operation outside the landing area. W_{ty} may be determined from the static distribution of the load or in the absence of specific information shared equally between the tyres. The loads for non-pneumatic tyres will be specially considered.

10.10.3 Parking areas may not be taken less than two frame spaces or the tyre width plus 500 mm whichever is the greater. Consideration should be given to the use of removable lagging around these areas and at the adjacent beam bulkhead connection.

10.10.4 Additional forces from tie down arrangements on the structure need only be considered if the tensioning force applied exceeds that imposed by the forces from ship motions as defined in *Vol 1, Pt 4, Ch 2, 10.14 Aircraft tie-downs*.

10.10.5 Decks subjected to a combination of parking and significant in-plane stresses will be specially considered.

10.11 Assisted take off

10.11.1 Where the aircraft jet is not parallel to the deck at the moment of launch or jet blast deflectors are used the structure is to be capable of withstanding the thermal loads imposed on the deck.

10.11.2 The structure of ramps used to assist take off are to be specially considered.

10.11.3 Structure surrounding catapults is to be effectively supported and designed for the maximum forces imposed by the launch system using the stress criteria given in *Table 5.3.2 Allowable stress factors f 1* in Pt 6, Ch 5.

10.12 Arrested landing

10.12.1 Structure surrounding arresting gear is to be effectively supported and designed for the maximum forces imposed by the arrested aircraft using the stress criteria given in *Table 5.3.2 Allowable stress factors f 1* in Pt 6, Ch 5.

10.13 Vertical recovery

10.13.1 The structure in way of the landing area and approach path is to be capable of withstanding the thermal loads imposed by hot exhaust gases.

10.14 Aircraft tie-downs

10.14.1 Aircraft tie-downs or general anchoring points are to be provided on the flight deck and in hangar spaces and are to be flush with the deck, when not in use.

10.14.2 The forces to be used in assessing the tie-down points are to preferably be determined with regards to specific aircraft but where the aircraft is unknown the designer may propose reasonable assumptions. Consideration is to be given to the range of angles of application of the force due to the relationship between the aircraft undercarriage arrangement and the spacing and arrangement of the tie-down points.

10.14.3 Tie-down points are to be tested in accordance with a suitable testing regime agreed with LR.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull and multi-hull ships of steel construction as defined in *18, Ch 1, 1 Background*.

1.2 Symbols and definitions

1.2.1 The symbols and definitions used in this Chapter are defined below and in the appropriate Section:

s = stiffener spacing, in mm

k_s = higher tensile steel factor, *see Vol 1, Pt 6, Ch 5, 3.1 Design criteria 3.1.1*.

■ *Section 2* Vehicle decks and fixed ramps

2.1 General

2.1.1 These requirements are applicable to longitudinally or transversely framed ships intended for the carriage of tracked vehicles, wheeled vehicles, or where wheeled vehicles are to be used for cargo handling.

2.1.2 The deck and supporting structure are to be designed on the basis of the maximum loading to which they may be subjected in service. Where applicable, the hatch covers are to be similarly designed. In no case, however, are the scantlings to be less than would be required for a weather or cargo deck, or hatch cover, as applicable.

2.1.3 Details of the deck loading resulting from the proposed stowage or operation of vehicles are to be supplied by the Builder. These details are to include axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. The vehicle types and wheel loads for which the vehicle decks, including hatch covers where applicable, have been approved are to be included in the ship's documentation and contained in a notice displayed on each deck. For wheeled vehicles, the wheel loading is to be taken as not less than 3,0 kN.

2.1.4 The scantling requirements are based on structural strength and limitations on stress and deflection, guidance for wear and tear allowances is given in *Vol 1, Pt 4, Ch 3, 2.3 Deck plating*. Local reinforcement is to be fitted as necessary, particularly in way of vehicle lanes and embarked personnel routes.

2.1.5 The webs of vehicle deck stiffening members are in no cases to be scalloped.

2.1.6 If wheeled vehicles are to be used on insulated decks or tanks tops, consideration will be given to the permissible loading in association with the insulation arrangements and the plating thickness.

2.1.7 Suitable fire fighting equipment and services should be provided in the vehicle space. Arrangements should be made for ventilation and drainage of spilt fuel.

2.2 Definitions

2.2.1 **Load Area.** The load area is defined as the footprint area of an individual wheel or the area enclosing a group of wheels when the distance between footprints is less than the smaller dimension of the individual prints.

2.3 Deck plating

2.3.1 The thickness, t_p, of vehicle deck plating is to be taken as not less than:

$$t_p = \frac{\alpha\, s}{1000\sqrt{k_s}} \text{ mm}$$

where

α = thickness coefficient obtained from *Figure 3.2.1 Tyre print chart* using a value of β given by

β = tyre print coefficient used in *Figure 3.2.1 Tyre print chart*

$$= log^{10}\left(\frac{F_{typ} k_s 2}{9{,}81 s^2}\right) \times 10^7$$

s = secondary stiffener spacing, in mm

F_{typ} = corrected patch load for plating, in kN obtained from *Table 3.2.1 Deck plate thickness calculation*, *see also Figure 3.2.1 Tyre print chart* and *Table 3.2.2 Tyre correction factor, n*

s and k_s are as defined in *Vol 1, Pt 4, Ch 3, 1.2 Symbols and definitions*.

Table 3.2.1 Deck plate thickness calculation

Symbols	Expression
a, *s*, *u* and *v* as defined in *Figure 3.2.1 Tyre print chart* n = tyre correction factor as detailed in *Table 3.2.2 Tyre correction factor, n* F_{typ} = corrected patch load for plating, in kN λ = dynamic magnification factor W_{ty} = load, in kN, on the tyre print. For closely spaced wheels the area shown in *Figure 2.10.2 Tyre patch dimensions* may be taken as the combined print φ_1 = patch aspect ratio correction factor φ_2 = panel aspect ratio correction factor φ_3 = wide patch load factor	$F_{typ} = \varphi_1 \varphi_2 \varphi_3 \lambda W_{ty}$
	$\varphi_1 = \dfrac{2v_1 + 1{,}1s}{u_1 + 1{,}1s}$ v_1 = v, but $\leq s$ u_1 = u, but $\leq a$
	$\varphi_2 = 1{,}0$ for $u \leq (a - s)$ $= \dfrac{1}{1{,}3 - \dfrac{0{,}3}{s}(a - u)}$ for $a \geq u > (a - s)$ $= 0{,}77 \dfrac{a}{u}$ for $u > a$
	$\varphi_3 = 1{,}0$ for $v < s$ $= 0{,}6\,(s/v) + 0{,}4$ for $1{,}5 > (v/s) > 1{,}0$ $= 1{,}2\,(s/v)$ for $(v/s) \geq 1{,}5$
	λ = 1,25 for harbour conditions = $(1 + 0{,}7n)$ for sea gong conditions

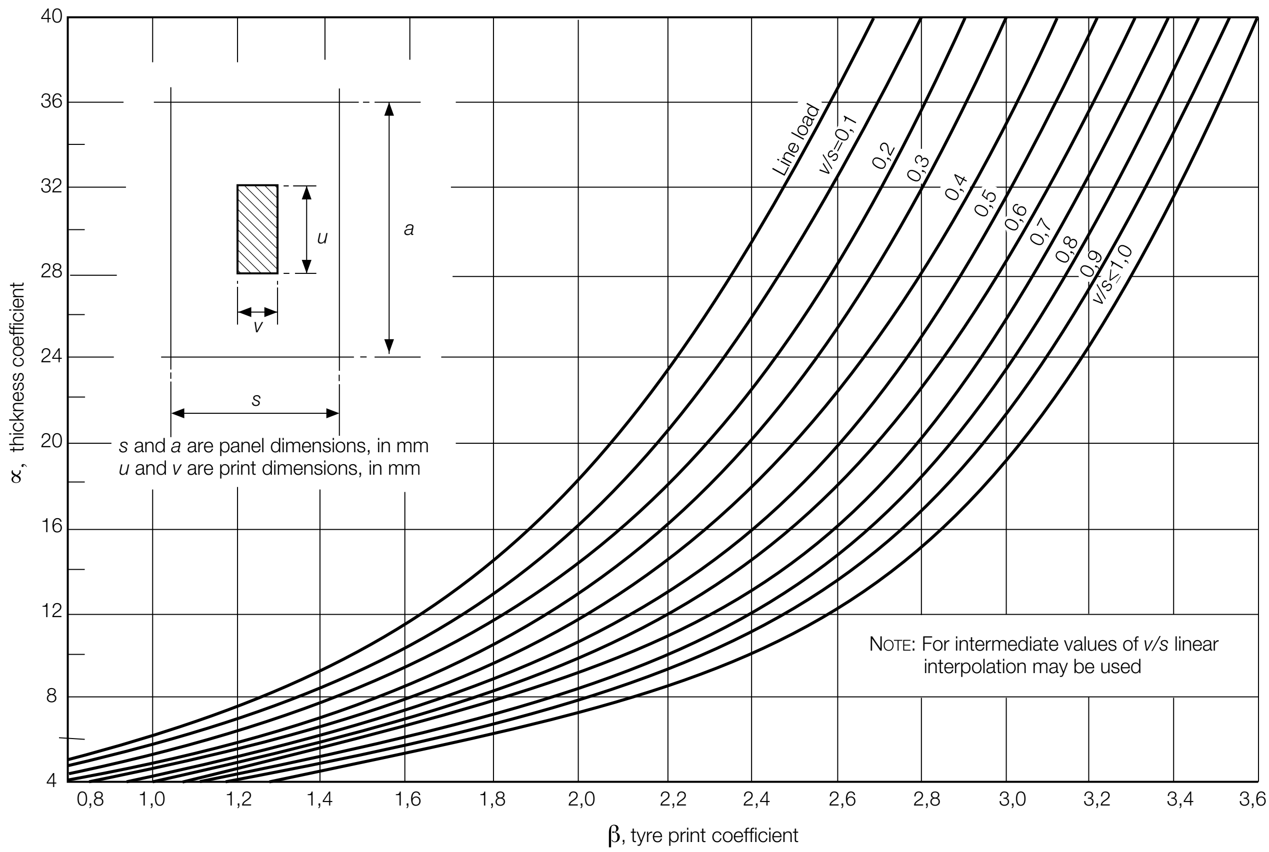


Figure 3.2.1 Tyre print chart

Table 3.2.2 Tyre correction factor, *n*

Number of wheels in idealised patch	Pneumatic tyres correction factor, *n*	Solid rubber tyres correction factor, *n*
1	0,6	0,8
2 or more	0,75	0,9

2.3.3 Where transversely framed decks contribute to the hull girder strength or where secondary stiffening is fitted perpendicular to the direction of vehicle lanes, the thickness, t_p, derived from *Vol 1, Pt 4, Ch 3, 2.3 Deck plating 2.3.1* is to be increased by 1,0 mm.

2.3.4 In the absence of a specific requirement the thickness t_p derived from *Vol 1, Pt 4, Ch 3, 2.3 Deck plating 2.3.1* is to be increased by a wear and wastage allowance of 1,5 mm for strength decks, weather decks, tank tops and inner bottom or 0,75 mm elsewhere.

2.4 Secondary stiffening

2.4.1 The scantlings of vehicle deck stiffeners are to satisfy the most severe arrangement of print wheel loads.

2.4.2 The minimum requirements for section modulus, inertia and web area of vehicle deck secondary stiffeners subject to wheel loading are to be calculated in accordance with *Table 3.2.3 Secondary stiffener requirements* using the loads defined in *Table 3.2.4 Design load cases for primary and secondary stiffening and supporting structure*.

Table 3.2.3 Secondary stiffener requirements

Scantling requirement	Load case $d \le l$	Load case $d > l$
Section modulus (Z) (cm^3)	$Z = \left(\frac{k_w F_{tys}(3l^2 - d^2)}{24l} + \frac{P_{tyw} s l^2}{10} + \frac{F_{tym} l}{10}\right)\frac{10^3}{f_\sigma \sigma_o}$	$Z = \left(\frac{k_w F_{tys} l^2}{10\,d} + \frac{P_{tyw} s l^2}{10} + \frac{F_{tym} l}{10}\right)\frac{10^3}{f_\sigma \sigma_o}$
Inertia (I)(cm^4)	$I = \left(\frac{k_w F_{tys}(2l^3 - 2d^2 l + d^3)}{384l} + \frac{P_{tyw} s l^3}{288} + \frac{F_{tym} l^2}{288}\right)\frac{10^5}{f_\delta E}$	$I = \left(\frac{k_w F_{tys} l^3}{384d} + \frac{P_{tyw} s l^3}{288} + \frac{F_{tym} l^2}{288}\right)\frac{10^5}{f_\delta E}$
Web area (A_w) (cm^2)	$A_w = \left(\frac{k_w F_{tys}(m^3 - 2m^2 + 2)}{2} + \frac{P_{tyw} s l}{2} + \frac{F_{tym}}{2}\right)\frac{10}{f_\tau \tau_o}$ where $m = d/l$	$A_w = \left(\frac{k_w F_{tys} l}{2d} + \frac{P_{tyw} s l}{2} + \frac{F_{tym}}{2}\right)\frac{10}{f_\tau \tau_o}$

Symbol

l = overall secondary stiffener length, in metres

s = stiffener spacing, in metres

d = dimension of load area parallel to stiffener axis, in metres

E = Young's Modulus of elasticity of material, in N/mm^2

w = dimension of load area perpendicular to stiffener axis, in metres

k_w = lateral loading factor
= 1 for $w \le s$
= s/w for $w > s$

F_{tys} = point load given in Table 3.2.4, in kN

F_{tym} = self weight load given in Table 3.2.4, in kN

P_{tyw} = weather deck load given in Table 3.2.4, in kN/m^2

f_σ,f_δ,f_τ are the structural design factors given in Pt 6, Ch 5

σ_o = specified minimum yield strength of the material, in N/mm^2

τ_o = shear strength of the material, in N/mm^2
= $\frac{\sigma_o}{\sqrt{3}}$

Table 3.2.4 Design load cases for primary and secondary stiffening and supporting structure

Condition	Loading		
	Stiffening		
	UDL P_{tyw} kN /m^2	Point loads, F_{tys} kN	Self weight, F_{tym} kN
Manoeuvring internal	-	1,6W_{ty}1,75W_{ty}	$(1 + a_z)W_s$
Manoeuvring external	0,5	$(1+ n\, a_z)W_{ty}$	$(1 + a_z)W_s$
Parking internal	-	1,1	$(1 + a_z)W_s$
Parking external	2	$(1+ n\, a_z)W_{ty}$	$(1 + a_z)W_s$
Symbols			
W_{ty} = maximum effective load per wheel or group of wheels W_s = structural weight of stiffener and supported structure, in kN UDL = uniformly distributed load over entire vehicle area, kN/m^2 n = tyre correction factor in *Table 3.2.3 Secondary stiffener requirements* a_z is defined in *Vol 1, Pt 5, Ch 3, 2 Motion response*			
Note 1. For the design of the supporting structure for vehicle decks, the applicable self weight and horizontal loads are to be added to the parking area loads. Note 2. The vehicles are to be positioned so as to produce the most severe loading condition for each structural member under consideration. Note 3. Stiffening members may have more than one point load acting at any time.			

2.4.3 When two or more load areas are located simultaneously on the same stiffener span, the scantling requirements are to be specially considered on the basis of direct calculation.

2.5 Primary stiffening

2.5.1 Generally the scantlings of vehicle deck primary girders and transverse web frames are to be determined on the basis of direct calculation in association with the loads defined in *Table 3.2.4 Design load cases for primary and secondary stiffening and supporting structure* and the limiting permissible stresses and deflection criteria contained in *Vol 1, Pt 6, Ch 5 Structural Design Factors*

2.6 Securing arrangements

2.6.1 The strength and stiffness of the holding down arrangements and supporting structure are to be in accordance with *Vol 1, Pt 4, Ch 1, 5.2 Vehicle and equipment holding down arrangements*.

2.6.2 Deck fittings in way of vehicle lanes are to be recessed.

2.6.3 The vehicle deck structure is to be of adequate strength for the upward forces imposed at fixed securing points. Local reinforcement is to be fitted as necessary.

2.7 Access

2.7.1 Bow doors are to comply with the requirements of *Vol 1, Pt 4, Ch 3, 4 Side, stern doors and other shell openings*.

2.7.2 Where access to the vehicle deck is provided by side and stern doors, the doors are to have scantlings equivalent to the structure in which they are fitted, *see also Vol 1, Pt 3, Ch 4, 5 Side scuttles and windows*.

2.7.3 Doors providing access between vehicle decks and accommodation spaces are to be gastight, have scantlings equivalent to the surrounding structure and where applicable are to comply with the specified fire safety standard.

2.8 Hatch covers

2.8.1 The scantlings and arrangements of hatches and hatch covers located within vehicle decks are to be not less than that required by the Rules for the supporting structure in which such hatches are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

2.8.2 In no case, however, are the scantlings of plating and stiffeners to be less than would be required for a weather or cargo deck hatch cover, as applicable.

2.8.3 Where unusual arrangements of hatch cover stiffening are proposed, the scantlings of plating and stiffeners may be determined by direct calculations. The designers calculations are to be submitted.

2.9 Heavy and special loads

2.9.1 Where heavy or special loads are proposed to be carried, the scantlings and arrangements of the deck structure will be individually considered on the basis of submitted calculations.

2.9.2 Due account is to be taken of the acceleration levels due to ship motion as applicable to particular items of heavy mass such as vehicles, containers, pallets, etc.

2.10 Tracked and steel wheeled vehicles

2.10.1 Where it is proposed to carry tracked vehicles the patch dimensions may be taken as the track print dimensions and F_{w} is to be taken as half the total weight of the vehicle. Deck fittings in way of vehicle lanes are to be recessed.

2.10.2 Where it is proposed to carry tracked vehicles, the total weight of the vehicle is to be used when determining the section modulus of the transverse at the top of a ramp or at other changes of gradient.

2.10.3 A wear and tear allowance is to be added to the plating thickness and it is not to be less than that defined in *Vol 1, Pt 4, Ch 3, 2.3 Deck plating 2.3.4*

2.11 Openings in main vehicle deck

2.11.1 Items such as portable plates in main vehicle deck for the removal of machinery parts, etc. may be arranged flush with the deck, provided they are secured by gaskets and closely spaced bolts at a pitch not exceeding five diameters.

2.11.2 Scuppers from vehicle or cargo spaces fitted with an approved fixed pressure water spray fire-extinguishing system are to be led inboard to tanks. Alternatively they may be led overboard providing they comply with *Vol 1, Pt 3, Ch 4, 8.1 General 8.1.3*.

2.11.3 Inboard draining scuppers do not require valves but are to be led to suitable drain tanks (not engine room or hold bilges) and the capacity of the tanks is to be sufficient to hold at least 20 minutes of drenching water. The arrangements for emptying these tanks are to be approved and suitable high level alarms provided.

2.11.4 Air pipes from cofferdams or void spaces may terminate in the enclosed ‘tween deck space on the main vehicle deck provided the space is adequately ventilated and the air pipes are provided with weathertight closing appliances.

2.11.5 In addition, the requirements of *Vol 1, Pt 4, Ch 3, 3.10 Securing and locking arrangements 3.10.8*are to be complied with.

2.12 Direct calculations

2.12.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative to and equivalent to those derived by Rule requirements. The assumptions made and the calculation procedures used are to be submitted for appraisal in accordance with *Vol 1, Pt 3, Ch 1, 2 Direct calculations*

Section 3
Bow doors

3.1 Application

3.1.1 The requirements of this Section are applicable to the arrangement, strength and securing of bow doors, both the visor and the side opening type doors, and inner doors leading to a complete or long forward enclosed superstructure, or to a long non-enclosed superstructure which is fitted to attain minimum bow height equivalence.

3.1.2 Other types of bow door will be specially considered.

3.1.3 Where the operational requirements dictate that the doors and ramps be deployed at sea or in the surf zone, the strength and operation will be specially considered.

3.2 General

3.2.1 The attention of Owners and Builders is drawn to the additional statutory regulations for bow doors that may be required by the subdivision and stability standard.

3.2.2 Bow doors are to be located above the vertical limit of watertight integrity. A watertight recess is normally permitted below the vertical limit of watertight integrity located forward of the collision bulkhead and above the deepest waterline, for the arrangement of ramps or other related mechanical devices. For any ship where bow doors may be open at sea or located below the vertical limit of watertight integrity, the enclosed spaces protected by the door or ramp are to be considered open as well as closed in damage stability or flooding conditions.

3.2.3 An inner door is to be fitted which is to be gasketed and weathertight. The inner door is to be part of the collision bulkhead. The inner door need not be fitted directly above the bulkhead below, provided it is located within the limits specified for the position of the collision bulkhead, *see Vol 1, Pt 3, Ch 2, 4 Bulkhead arrangements*. A vehicle ramp may be arranged for this purpose, provided its position complies with *Vol 1, Pt 3, Ch 2, 4 Bulkhead arrangements* and the ramp is weathertight over its complete length. In this case the upper part of the ramp higher than 2,3 m above the vertical limit of watertight integrity may extend forward of the limit specified in *Vol 1, Pt 3, Ch 2, 4 Bulkhead arrangements* If this is not possible a separate inner weathertight door is to be installed, as far as practicable within the limits specified for the position of the collision bulkhead.

3.2.4 Bow doors are to be fitted as to ensure tightness consistent with operational conditions and to give effective protection to inner doors. Inner doors forming part of the collision bulkhead are to be weathertight over the full height of the vehicle space and arranged with fixed sealing supports on the aft side of the doors.

3.2.5 Bow doors and inner doors are to be arranged so as to preclude the possibility of the bow door causing structural damage to the inner door or to the collision bulkhead in the case of damage to or detachment of the bow door. If this is not possible, a separate inner weathertight door is to be installed, as indicated in *Vol 1, Pt 4, Ch 3, 3.2 General 3.2.3*.

3.2.6 The requirements for inner doors are based on the assumption that vehicles are effectively lashed and secured against movement in the stowed position.

3.2.7 The scantlings and arrangements of side shell and stern doors are to be in accordance with the requirements of *Vol 1, Pt 6, Ch 3 Scantling Determination*.

3.3 Symbols and definitions

3.3.1 The symbols used in this Section are defined as follows:

A_s = area stiffener web, in cm^2

A_x = area, in m^2, of the transverse vertical projection of the bow door, between the bottom of the door and the top of the door or between the bottom of the door and the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser, *see Figure 3.3.2 Bow visor upward hinging*. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is lesser. In determining the height from the bottom of the door to the upper deck or to the top of the door, the bulwark is to be excluded.

A_y = area, in m^2, of the longitudinal vertical projection of the bow door, between the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser, *see Figure 3.3.2 Bow visor upward hinging*. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is the lesser.

A_z = area, in m^2, of the horizontal projection of the bow door, between the bottom of the door and the top of the upper deck bulwark, or between the bottom of the door and the top of the door, including the bulwark, where it is part of the door, whichever is the lesser, *see Figure 3.3.2 Bow visor upward hinging*. Where the flare angle of the bulwark is at least 15 degrees less than the flare angle of the adjacent shell plating, the height from the bottom of the door may be measured to the upper deck or to the top of the door, whichever is the lesser.

a_{bv} = vertical distance, in metres, from visor pivot to the centroid of the transverse vertical projected area of the visor door, as shown in *Figure 3.3.2 Bow visor upward hinging*

b_{bv} = horizontal distance, in metres, from visor pivot to the centroid of the horizontal projected area of the visor door, as shown in *Figure 3.3.2 Bow visor upward hinging*

c_{bv} = horizontal distance, in metres, from visor pivot to the centre of gravity of visor mass, as shown in *Figure 3.3.2 Bow visor upward hinging*

d_{bv} = vertical distance, in metres, from bow door pivot to the centre of gravity of the bow door, *see Figure 3.3.2 Bow visor upward hinging*

h = height of the door between the levels of the bottom of the door and the upper deck or between the bottom of the door and the top of the door, in metres, whichever is the lesser, as shown in *Figure 3.3.1 Definition of αf and βe*

k_s = higher tensile steel factor defined in *Vol 1, Pt 6, Ch 5, 3.1 Design criteria 3.1.1*

Q_{bd} = shear force, in kN, in the stiffener calculated by using uniformly distributed external pressure P_e as given in *Figure 3.3.1 Definition of αf and βe*

W_{bv} = mass of the visor door, in tonnes

W = breadth of the door at a height h/2 above the bottom of the door, in metres, as shown in *Figure 3.3.2 Bow visor upward hinging*

l_d = length of the door at a height h/2 above the bottom of the door, in metres, as shown in *Figure 3.3.2 Bow visor upward hinging*

τ = shear stress, in N/mm^2

σ = bending stress, in N/mm^2

σ_o = specified minimum yield strength of the material, in N/mm^2

σ_{eq} = equivalent stress, in N/mm^2

$$= \sqrt{\sigma^2 + 3\tau^2}$$

3.3.2 **Locking device.** A device that locks a securing device in the closed position.

3.3.3 **Securing device.** A device used to keep the door closed by preventing it from rotating about its hinges.

3.3.4 **Side-opening doors.** Side-opening doors are opened either by rotating outwards about a vertical axis through two or more hinges located near the outboard edges or by horizontal translation by means of linking arms arranged with pivoted attachments to the door and the craft. It is anticipated that side-opening doors are arranged in pairs.

3.3.5 **Supporting device.** A device used to transmit external or internal loads from the door to a securing device and from the securing device to the ship's structure, or a device other than a securing device, such as a hinge, stopper or other fixed device, that transmits loads from the door to the ship's structure.

3.3.6 **Visor doors.** Visor doors are opened by rotating upwards and outwards about a horizontal axis through two or more hinges located near the top of the door and connected to the primary structure of the door by longitudinally arranged lifting arms.

3.4 Construction and testing

3.4.1 Plans are to be of sufficient detail for plan approval purposes. Plans showing the proposed scantlings and arrangement of the bow door are to be submitted. Bow doors are to be constructed under survey.

3.4.2 Bow doors fitted below the limit of watertight integrity are to be subject to a pressure test of a prototype to confirm the design pressure head.

3.4.3 As an alternative to prototype testing, the integrity of the door may be demonstrated by calculation and representative testing in accordance with *MSC/Circular.1176 – Unified Interpretations to SOLAS Chapters II-1 and XII and to the Technical Provisions for Means of Access for Inspections – (25 May 2005)* . For doors fitted above the vertical limit of watertight integrity, the doors only require testing following installation, in accordance with *Table 6.6.1 Testing requirements* in Pt 6, Ch 6.

3.5 Strength criteria

3.5.1 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be able to withstand the design loads defined in *Vol 1, Pt 4, Ch 3, 3.6 Design loads*. The shear, bending and equivalent stresses are not to exceed $80/k$ N/mm^2, $120/k$ N/mm^2 and $150/k_s$ N/mm^2 respectively.

3.5.2 The buckling strength of primary members is to be verified as being adequate, *see Vol 1, Pt 6, Ch 2, 3 Buckling*

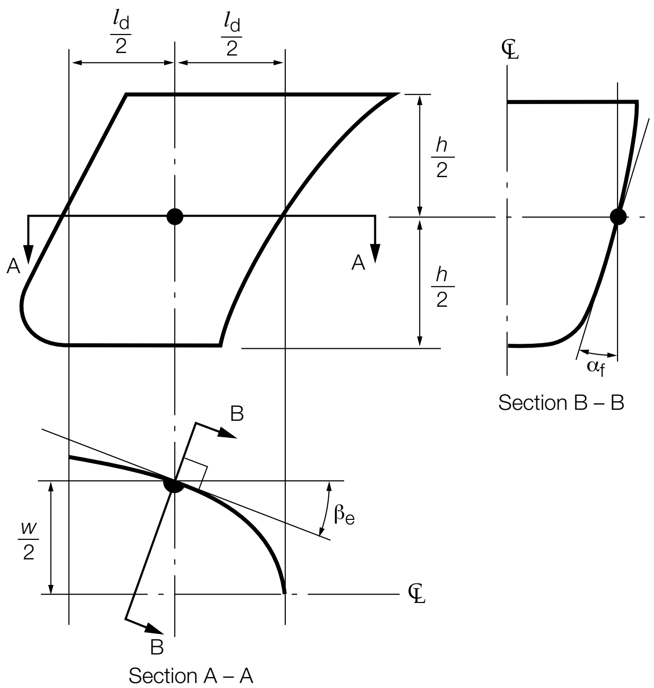


Figure 3.3.1 Definition of α_f and β_e

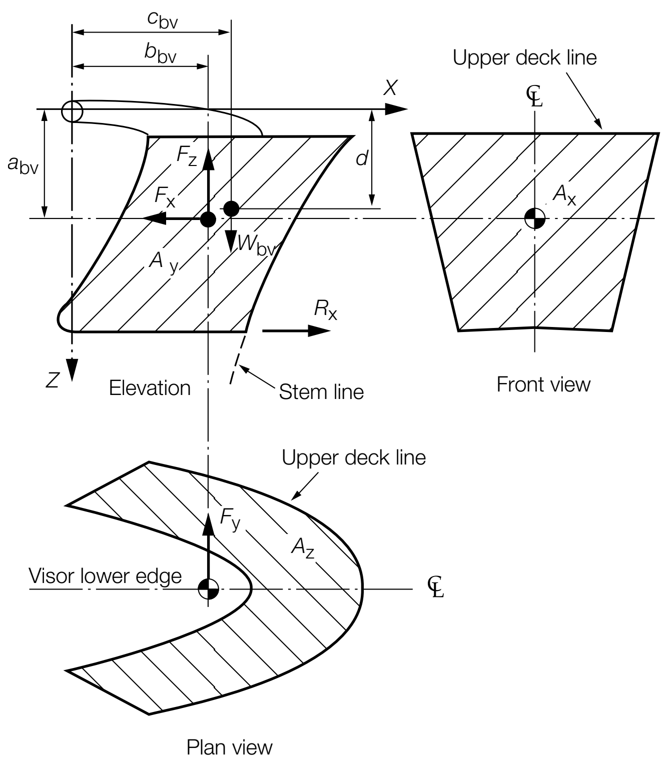


Figure 3.3.2 Bow visor upward hinging

3.5.3 For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed 80 per cent of the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification.

3.5.4 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of steel bolts not carrying support forces is not to exceed 125/*k* N/mm^2.

3.6 Design loads

3.6.1 The design external pressure, P_e, for the determination of scantlings for primary members, securing and supporting devices of bow doors is to be taken not less than the following:

$$P_e = 2,75\,\lambda_G C_H\left(0,22 + 0,15 tan\,\alpha_f\right) \text{x} \left(0,4V_{max}\sin\beta_e + 0,6L_R{}^{0,5}\right)^2 \text{ kN/m}^2$$

V_{max} = maximum speed, in knots, as defined in *Vol 1, Pt 1, Ch 2, 2.2 Definitions 2.2.5*.

L_R = Rule length of ship, in metres, as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars 5.2.2*

λ_G = service area factor for mono-hull ships, *see Vol 1, Pt 1, Ch 2, 3.6 Service area notations*

= 1,0 for sea-going ships

= 0,8 for ships operated in coastal waters

= 0,5 for ships operated in sheltered waters

C_H = 0,0125L_R for L_R < 80 m

= 1,0 for $L_R \geq 80$ m

α_f = flare angle, in degrees, at the point to be considered, defined as the angle between a vertical line and the tangent to the side shell plating, measured in a vertical plane normal to the horizontal tangent to the shell plating, *see Figure 3.3.1 Definition of αf and βe*

β_e = entry angle, in degrees, at the point to be considered, defined as the angle between a longitudinal line parallel to the centreline and the tangent to the shell plating in a horizontal plane, *see Figure 3.3.1 Definition of αf and βe*.

3.6.2 The design external forces, F_x, F_y and F_z, in kN, for the determination of scantlings of securing and supporting devices of bow doors are taken to be not less than $P_e A_x$, $P_e A_y$ and $P_e A_z$ respectively. Where P_e is the external pressure, defined in *Vol 1, Pt 4, Ch 3, 3.6 Design loads 3.6.1*, with the flare angle, α_f, and the entry angle, β_e, measured at the point on the bow door, $l_d/2$ aft of the stem line on the plane $h/2$ above the bottom of the door, as shown in *Figure 3.3.1 Definition of αf and βe*. A_x, A_y, A_z and h as defined in *Vol 1, Pt 4, Ch 3, 3.3 Symbols and definitions 3.3.1*

3.6.3 For bow doors, including bulwark, of unusual form or proportions, the areas used for the determination of the design values of external forces will be specially considered.

3.6.4 For visor doors the closing moment, M_y, under external loads, is to be taken as:

$$M_y = F_x a_{bv} + 10 W_{bv} c_{bv} - F_z b_{bv} \text{ kNm}$$

where

W_{bv}, a_{bv}, b_{bv} and c_{bv} as defined in *Vol 1, Pt 4, Ch 3, 3.3 Symbols and definitions 3.3.1*, F_x and F_z as defined in *Vol 1, Pt 4, Ch 3, 3.6 Design loads 3.6.2*.

3.6.5 The lifting arms of a visor and its supports are to be dimensioned for the static and dynamic forces applied during the lifting and lowering operations, and a minimum wind pressure of 1,5 kN/m^2 is to be taken.

3.6.6 The design external pressure, in kN/m^2, for the determination of scantlings for primary members, securing and supporting devices and surrounding structure of inner doors is to be taken as the greater of $0{,}45L_R$ and $10h^2$, where h^2 is the distance, in m, from the load point to the top of the space enclosed by the visor, L_R, as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars 5.2.2*

3.6.7 The design internal pressure for the determination of scantlings for securing devices of inner doors is not to be taken less than 25 kN/m^2.

3.6.8 On ships with rounded nose bow and a large stem angle with the waterline, strengthening against horizontal impact loads is to be considered. Similarly, in ships with a flare angle of less than 60^o with the waterline, strengthening against vertical impact loads to be considered.

3.7 Scantlings of bow doors

3.7.1 The strength of bow doors is to be equivalent to the surrounding structure.

3.7.2 Bow doors are to be adequately stiffened and means are to be provided to prevent lateral or vertical movement of the doors when closed. For visor doors adequate strength for the opening and closing operations is to be provided in the connections of the lifting arms to the door structure and to the craft structure.

3.7.3 The thickness of the bow plating is not to be less than that required for the side shell plating, using bow door stiffener spacing, but in no case less than the minimum required thickness of fore end shell plating.

3.7.4 The section modulus of horizontal or vertical stiffeners is not to be less than that required for end framing. Consideration is to be given, where necessary, to differences in fixity between ship's frames and bow doors stiffeners.

3.7.5 The stiffener webs are to have a net sectional area, A_s, not less than:

$$A_s = \frac{23{,}5 Q_{bd}}{\sigma_o} \text{ cm}^2$$

where A_s, Q_{bd} and σ_o as defined in *Vol 1, Pt 4, Ch 3, 3.3 Symbols and definitions 3.3.1*

3.7.6 The bow door secondary stiffeners are to be supported by primary members constituting the main stiffening of the door.

3.7.7 The primary members of the bow door and the hull structure in way are to have sufficient stiffness to ensure integrity of the boundary support of the door.

3.7.8 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in *Vol 1, Pt 4, Ch 3, 3.6 Design loads 3.6.1* and permissible stresses given in *Vol 1, Pt 4, Ch 3, 3.5 Strength criteria 3.5.1*. In general, formulae for simple beam theory may be applied to determine the bending stress. Members are to be considered to have simply supported end connections.

3.7.9 The webs of primary members are to be adequately stiffened, preferably in a direction perpendicular to the shell plating.

3.8 Scantlings of inner doors

3.8.1 Scantlings of the primary members are generally to be supported by direct calculations in association with the external pressure given in *Vol 1, Pt 4, Ch 3, 3.6 Design loads 3.6.1* and permissible stresses given in *Vol 1, Pt 4, Ch 3, 3.5 Strength criteria 3.5.1* In general, formulae for simple beam theory may be applied to determine the bending stress. Members are to be considered to have simply supported end connections.

3.8.2 Where inner doors also serve as vehicle ramps, the scantlings are not to be less than those required for vehicle decks.

3.8.3 The distribution of forces acting on the securing and supporting devices is, in general, to be supported by direct calculations taking into account the flexibility of the structure and actual position and stiffness of the supports.

3.9 Securing and supporting of bow doors

3.9.1 Bow doors are to be fitted with adequate means of securing and supporting so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the bow doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of a comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is, in general, not to exceed 3 mm. A means is to be provided for mechanically fixing the door in the open position.

3.9.2 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be included and considered to calculate the reaction forces acting on the devices. Small and/or flexible devices such as cleats intended to provide load compression of the packing material are, in general, not to be included in the calculations called for in *Vol 1, Pt 4, Ch 3, 3.9 Securing and supporting of bow doors 3.9.8*. The number of securing and supporting devices are, in general, to be the minimum practical whilst taking into account the requirements for redundant provision given in *Vol 1, Pt 4, Ch 3, 3.9 Securing and supporting of bow doors 3.9.9* and *Vol 1, Pt 4, Ch 3, 3.9 Securing and supporting of bow doors 3.9.10* and the available space for adequate support in the hull structure.

3.9.3 For opening outwards visor doors, the pivot arrangement is generally to be such that the visor is self closing under external loads, that is $M_y > 0$. Moreover, the closing moment, M_y, as given in *Vol 1, Pt 4, Ch 3, 3.6 Design loads 3.6.4*, is to be not less than:

$$M_y = 10 W_{bv} c_{bv} + 0{,}1 (a_{bv}^2 + b_{bv}^2)^{0{,}5} (F_x^2 + F_z^2)^{0{,}5}$$

where W_{bv}, a_{bv}, b_{bv} and c_{bv} as defined in *Vol 1, Pt 4, Ch 3, 3.3 Symbols and definitions 3.3.1*, F_x and F_z as defined in *Vol 1, Pt 4, Ch 3, 3.6 Design loads 3.6.2*

3.9.4 Securing and supporting devices are to be adequately designed so that they can withstand the reaction forces within the permissible stresses given in *Vol 1, Pt 4, Ch 3, 3.5 Strength criteria 3.5.1*

3.9.5 For visor doors the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door.

Case 1	F_x and F_z
Case 2	$0{,}7F_y$ acting on each side separately together with $0{,}7F_x$ and $0{,}7F_z$.

where F_x, F_y and F_z are to be determined as indicated in *Vol 1, Pt 4, Ch 3, 3.6 Design loads 3.6.2* and applied at the centroid of projected areas.

3.9.6 For side-opening doors the reaction forces applied on the effective securing and supporting devices assuming the door as a rigid body are determined for the following combination of external loads acting simultaneously together with the self weight of the door:

Case 1	F_x, F_y and F_z acting on both doors.
Case 2	$0,7F_x$ and $0,7F_z$ acting on both doors and $0,7F_y$ acting on each door separately.

where F_x, F_y and F_z are to be determined as indicated in *Vol 1, Pt 4, Ch 3, 3.6 Design loads 3.6.2* and applied at the centroid of projected areas.

3.9.7 The support forces as determined according to *Vol 1, Pt 4, Ch 3, 3.9 Securing and supporting of bow doors 3.9.5* and *Vol 1, Pt 4, Ch 3, 3.9 Securing and supporting of bow doors 3.9.6* are generally to give rise to a zero moment about the transverse axis through the centroid of the area, Ax. For visor doors, longitudinal reaction forces of pin and/or wedge supports at the door base contributing to this moment are not to be of the forward direction.

3.9.8 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports.

3.9.9 The arrangement of securing and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable to withstand the reaction forces without exceeding by more than 20 per cent the permissible stresses as given in *Vol 1, Pt 4, Ch 3, 3.5 Strength criteria 3.5.1*.

3.9.10 For visor doors, two securing devices are to be provided at the lower part of the door, each capable of providing the full reaction force required to prevent opening of the door within the permissible stresses given in *Vol 1, Pt 4, Ch 3, 3.5 Strength criteria 3.5.1*. The opening moment, M_o, to be balanced by this reaction force, is not to be taken less than:

$$M_o = 10W_{bv} d_{bv} + 5A_x a_{bv} \text{ kNm}$$

where

W_{bv}, A_x, d_{bv} and a_{bv} as defined in *Vol 1, Pt 4, Ch 3, 3.3 Symbols and definitions 3.3.1*.

3.9.11 For visor doors, the securing and supporting devices excluding the hinges should be capable of resisting the vertical design force ($F_z - 10W_{bv}$), in kN, within the permissible stresses given in *Vol 1, Pt 4, Ch 3, 3.5 Strength criteria 3.5.1*.

3.9.12 All load transmitting elements in the design load path, from door through securing and supporting devices into the ship structure, including welded connections, are to be the same strength. These elements include pins, supporting brackets and back-up brackets. Where cut-outs are made in the supporting structure, the strength and stiffness will be specially considered.

3.9.13 For side-opening doors, thrust bearings have to be provided in way of girder ends at the closing of the two leaves to prevent one leaf to shift towards the other one under effect of unsymmetrical pressure, *see Figure 3.3.3 Typical thrust bearing*. Each part of the thrust bearing has to be kept secured on the other part by means of securing devices. Any other arrangement serving the same purpose is to be submitted for appraisal.

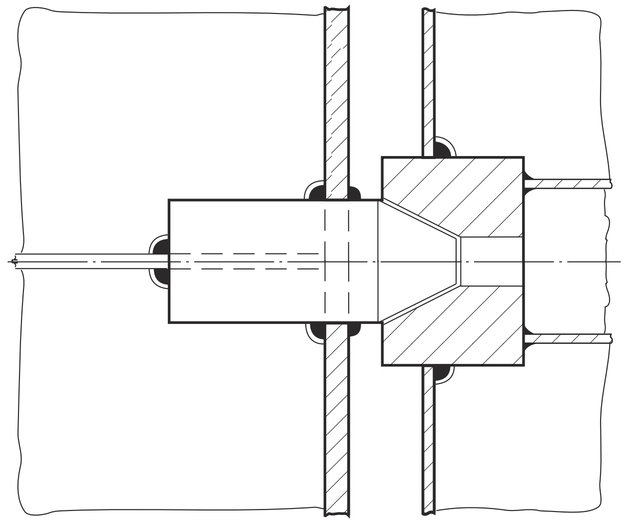


Figure 3.3.3 Typical thrust bearing

3.9.14 The spacing for side and top cleats should not exceed 2,5 m and there should be cleats positioned as close to the corners as practicable. Alternative arrangements for ensuring weathertight sealing will be specially considered.

3.10 Securing and locking arrangements

3.10.1 Securing devices are to be simple to operate and easily accessible. Securing devices are to be equipped with mechanical locking arrangement (self locking or separate arrangement), or be of the gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in the proper sequence.

3.10.2 Bow doors and inner doors giving access to vehicle decks are to be provided with an arrangement for remote control, from a position above the vertical limit of watertight integrity, of:

(a) the closing and opening of the doors, and
(b) associated securing and locking devices for every door.

Indication of the open/closed position of every door and every securing and locking device is to be provided at the remote control stations. The operating panels for operation of doors are to be inaccessible to unauthorised persons. A notice plate, giving instructions to the effect that all securing devices are to be closed and locked before leaving harbour, is to be placed at each operating panel and is to be supplemented by warning indicator lights.

3.10.3 Where hydraulic securing devices are applied, the system is to be mechanically lockable in closed position so that in the event of loss of the hydraulic fluid, the securing devices remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in closed position.

3.10.4 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on the operating panel to show that the bow door and inner door are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. The indicator lights are to be provided with a permanent power supply, further, arrangements are to be such that it is not possible to turn off these lights in service.

3.10.5 The indicator system is to be designed on the failsafe principle and is to show by visual alarms if the door is not fully closed and not fully locked and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors. The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.

3.10.6 The indication panel on the navigation bridge is to be equipped with a mode selection function 'harbour/sea voyage', so arranged that audible alarm is given if the ship leaves harbour with the bow door or inner door not closed and with any of the securing devices not in the correct position.

3.10.7 A water leakage detection system with audible alarm and television surveillance are to be arranged to provide an indication to the navigation bridge and to the engine control room of leakage through the inner door.

3.10.8 Between the bow door and the inner door a television surveillance system is to be fitted with a monitor on the navigation bridge and in the machinery control room. The system is to be able to monitor the position of doors and a sufficient number of their securing devices. Special consideration is to be given for lighting and contrasting colour of objects under surveillance.

3.10.9 A drainage system is to be arranged in the area between bow door and ramp, or where no ramp is fitted, between the bow door and inner door. The system is to be equipped with an audible and visual alarm function to the navigation bridge being set off when the water levels in these areas exceed 0,5 m or the high water level alarm, whichever is the lesser. If not discharged by a bilge suction, scuppers are to be provided port and starboard having a diameter of not less than 50 mm. Valves are to be fitted.

3.10.10 If the main vehicle deck is not totally enclosed, scuppers or freeing ports are to be provided consistent with the requirements of *Vol 1, Pt 3, Ch 4, 9 Bulwarks, guard rails, raised walkways and other means for the protection of crew and embarked personnel*.

3.10.11 Air pipes from cofferdams or void spaces may terminate in the enclosed ‘tween deck space on the main vehicle deck provided the space is adequately ventilated and the air pipes are provided with weathertight closing appliances.

3.11 Operating and Maintenance Manual

3.11.1 An Operating and Maintenance Manual for the bow door and inner door is to be provided on board. The manual is to contain the following information:

(a) main particulars and design drawings,

- special safety precautions;
- details of vessel, class and statutory certificates;
- equipment and design loading for ramps;
- key plan of equipment for doors and ramps;
- manufacturers' recommended testing for equipment; and
- a description of the following equipment: bow doors; inner bow doors; bow/ramp doors; central power pack; bridge panel; ramps leading down from the main deck; engine control room panel.

(b) service conditions:

- limiting heel and trim of the ship for loading/unloading;
- limiting heel and trim for door operations;
- operating instructions for doors and ramps; and
- emergency operating instructions for doors and ramps.

(c) maintenance:

- schedule and extent of maintenance;
- troubleshooting and acceptable clearances; and
- manufacturers' maintenance procedures.

(d) register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

This Manual is to be submitted for approval and is to contain a note recommending that recorded inspections of the door supporting and securing devices carried out by the ship’s staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of the doors. Any damages recorded during such inspections are to be reported to LR.

3.11.2 Documented operating procedures for closing and securing the bow door and inner door are to be kept on board and posted at an appropriate place.

■ Section 4
Side, stern doors and other shell openings

4.1 Symbols

4.1.1 The symbols used in this Section are defined as follows:

d = distance between closing devices, in metres

k_s = material factor, *see Vol 1, Pt 6, Ch 5, 3.1 Design criteria 3.1.1* but is not to be taken less than 0,72 unless demonstrated otherwise by a direct strength analysis with regard to relevant modes of failure

I = moment of inertia, in cm^4, of the stiffener or girder, in association with an effective width of attached plating determined in accordance with *Vol 1, Pt 6, Ch 2, 5 Dynamic loading*

σ = bending stress, in N/mm^2

σ_e = equivalent stress, in N/mm^2

$= \sqrt{\left(\sigma^2 + 3\tau^2\right)}$

σ_o = minimum yield stress of the bearing material, in N/mm^2

τ = shear stress, in N/mm^2

4.2 General

4.2.1 These requirements cover service doors in the ship side (abaft the collision bulkhead) and stern area, below the weather deck and in enclosed superstructures.

4.2.2 For the requirements of bow doors, *see Vol 1, Pt 4, Ch 3, 3 Bow doors*.

4.2.3 Side and stern doors are to be so fitted as to ensure tightness and structural integrity commensurate with their location and the surrounding structure, *see also Vol 1, Pt 3, Ch 1, 5 Definitions*

4.2.4 In general, the lower edge of door openings is not to be below a line drawn parallel to the design draught.

4.2.5 When the lower edge is below the design draught or doors below the vertical limit of watertight integrity are to be opened at sea, the arrangements will be specially considered. In general, the enclosed spaces protected by the door are to be considered open as well as closed in damage stability or flooding conditions.

4.2.6 Doors are generally to be arranged to open outwards, however inward opening doors will be considered provided strongbacks are fitted when the doors are situated in the first two lower decks above the waterline.

4.2.7 For ships complying with the requirements of this Section, the securing, supporting and locking devices are defined in *Vol 1, Pt 4, Ch 3, 3.3 Symbols and definitions*.

4.3 Construction and testing

4.3.1 Plans are to be of sufficient detail for plan approval purposes. Plans showing the proposed scantlings and arrangements of any side and stern doors or other shell openings are to be submitted. Side and stern doors or other shell openings are to be constructed under survey.

4.3.2 Side and stern doors fitted below the limit of watertight integrity are to be subject to a pressure test of a prototype to confirm the design pressure head.

4.3.3 As an alternative to prototype testing, the integrity of the door may be demonstrated by calculation and representative testing in accordance with *MSC/Circular.1176 – Unified Interpretations to SOLAS Chapters II-1 and XII and to the Technical Provisions for Means of Access for Inspections – (25 May 2005)* . For doors fitted above the vertical limit of watertight integrity, the doors only require testing following installation, in accordance with *Table 6.6.1 Testing requirements* in Pt 6, Ch 6.

4.4 Scantlings

4.4.1 In general the strength of side and stern doors is to be equivalent to the strength of the surrounding structure.

4.4.2 Door openings in the side shell are to have well rounded corners and adequate compensation is to be arranged with web frames at sides and stringers or equivalent above and below, *see Vol 1, Pt 3, Ch 1, 5 Definitions*.

4.4.3 Doors are to be adequately stiffened, and means are to be provided to prevent movement of the doors when closed. Adequate strength is to be provided in the connections of the lifting/manoeuvring arms and hinges to the door structure and to the ship structure.

4.4.4 The thickness of the door plating is to be not less than the shell plating calculated with the door stiffener spacing, and in no case to be less than the minimum adjacent shell thickness.

4.4.5 Where stern doors are protected against direct wave impact by a permanent external ramp, the thickness of the stern door plating may be reduced by 20 per cent relative to the requirements of *Vol 1, Pt 4, Ch 3, 4.4 Scantlings 4.4.4*. Those parts of the stern door which are not protected by the ramp are to have the thickness of plating in full compliance with *Vol 1, Pt 4, Ch 3, 4.4 Scantlings 4.4.4*.

4.4.6 Where higher tensile steel is proposed, the plating thickness required in *Vol 1, Pt 4, Ch 3, 4.4 Scantlings 4.4.4* and *Vol 1, Pt 4, Ch 3, 4.4 Scantlings 4.4.5* may be reduced by $\sqrt{k_s}$.

4.4.7 The section modulus of horizontal or vertical stiffeners is to be not less than required for the adjacent shell framing using the actual stiffener spacing. Consideration is to be given, where necessary, to differences in fixity between ship's frames and door stiffeners.

4.4.8 Where necessary, door secondary stiffeners are to be supported by primary members constituting the main stiffening elements of the door.

4.4.9 The scantlings of such primary members are to be based on direct strength calculations. Normally, formulae for simple beam theory may be applied to determine the bending stress. Members are to be considered to have simply supported end connections. The design load is the uniformly distributed external sea pressure, p_e, as defined in *Vol 1, Pt 4, Ch 3, 4.9 Design loads 4.9.1*. For minimum scantlings, p_e is to be taken as 25 kN/m^2 and the permissible stresses are as follows:

$$\tau = \frac{80}{k_s} \text{ N/mm}^2$$

$$\sigma = \frac{120}{k_s} \text{ N/mm}^2$$

$$\sigma_{\varepsilon} = \frac{150}{k_s} \text{ N/mm}^2$$

4.4.10 The webs of primary members are to be adequately stiffened, preferably in a direction perpendicular to the shell plating.

4.4.11 The stiffness of the edges of the doors and the hull structure in way are to be sufficient to ensure weathertight integrity. Edge stiffeners/girders are to be adequately stiffened against rotation and are to have a moment of inertia not less than:

$$l = 0{,}8\, P_L\, d^4 \text{ cm}^4$$

where

P_L = packing line pressure along edges, not to be taken less than 50 N/cm.

For edge girders supporting main door girders between securing devices, the moment of inertia is to be increased in relation to the additional force.

4.4.12 The buckling strength of primary members is to be specially considered.

4.4.13 All load transmitting elements in the design load path from door through securing and supporting devices into the ship structure, including welded connections, are to be to the same strength standard as required for the securing and supporting devices. These elements include pins, supporting brackets and back-up brackets. Where cut-outs are made in the supporting structure, the strength and stiffness will be specially considered.

4.5 Doors serving as ramps

4.5.1 Where doors also serve as vehicle ramps, the plating and stiffeners are to be not less than required for vehicle decks, *see Vol 1, Pt 4, Ch 3, 2 Vehicle decks and fixed ramps*

4.5.2 The design of the hinges for these doors should take into account the ship angle of trim or heel which may result in uneven loading of the hinges.

4.6 Closing, securing and supporting of doors

4.6.1 Doors are to be fitted with adequate means of closing, securing and support so as to be commensurate with the strength and stiffness of the surrounding structure. The hull supporting structure in way of the doors is to be suitable for the same design loads and design stresses as the securing and supporting devices. Where packing is required, the packing material is to be of comparatively soft type, and the supporting forces are to be carried by the steel structure only. Other types of packing may be considered. Maximum design clearance between securing and supporting devices is generally not to exceed 3 mm.

4.6.2 Devices are to be simple to operate and easily accessible. They are to be of an approved type.

4.6.3 Securing devices are to be equipped with mechanical locking arrangements (self locking or separate arrangements), or are to be of gravity type. The opening and closing systems as well as securing and locking devices are to be interlocked in such a way that they can only operate in a proper sequence.

4.6.4 Means are to be provided to enable the doors to be mechanically fixed in the open position taking into account the self weight of the door and a minimum wind pressure of 1,5 kN/m^2 acting on the maximum projected area in the open position.

4.6.5 The spacing for cleats or closing devices should not exceed 2,5 m and there should be cleats or closing devices positioned as close to the corners as practicable. Alternative arrangements for ensuring weathertight sealing will be specially considered.

4.7 Systems for operation

4.7.1 Doors with a clear opening area of 12 m^2 or greater are to be provided with closing devices operable from a remote control position. Doors which are located partly or totally below the vertical limit of watertight integrity with a clear opening area greater than 6 m^2 are to be provided with an arrangement for remote control from a position above the vertical limit of watertight integrity. This remote control is provided for the:

(a) Closing and opening of the doors.
(b) Associated securing and locking devices.

4.7.2 The location of the remote control panel is to be such that the opening/closing operation can be easily observed by the operator or by other suitable means such as closed circuit television.

4.7.3 A notice is to be displayed at the operating panel stating that the door is to be fully closed and secured preferably before, or immediately the ship leaves the berth and that this operation is to be entered in the ship's log.

4.7.4 Means are to be provided to prevent unauthorised operation of the doors.

4.7.5 Where hydraulic securing devices are applied, the system is to be mechanically lockable in the closed position so that in the event of hydraulic system failure, the securing devices will remain locked. The hydraulic system for securing and locking devices is to be isolated from other hydraulic circuits when in the closed position.

4.8 Systems for indication and monitoring

4.8.1 The following requirements apply to doors in the boundaries of special category spaces or vehicle spaces, through which such spaces may be flooded. For ships, where no part of the door is below the design waterline, doors that are to be opened at sea are above the vertical limit of watertight integrity, and the area of the door opening is not greater than 6 m^2, then the requirements of this Section need not be applied.

4.8.2 Separate indicator lights and audible alarms are to be provided on the navigation bridge and on each operating panel to indicate that the doors are closed and that their securing and locking devices are properly positioned. The indication panel is to be provided with a lamp test function. It is not to be possible to turn off the indicator light.

4.8.3 The indicator system is to be designed on the fail safe principle and is to indicate by visual alarms if the door is not fully closed and not fully locked, and by audible alarms if securing devices become open or locking devices become unsecured. The power supply for the indicator system is to be independent of the power supply for operating and closing the doors and is to be

provided with a back-up power supply. The sensors of the indicator system are to be protected from water, ice formation and mechanical damages.

4.8.4 The indication panel on the navigation bridge is to be equipped with a mode selection function 'harbour/sea voyage', so arranged that audible alarm is given if the vessel leaves harbour with side shell or stern doors not closed or with any of the securing devices not in the correct position.

4.9 Design loads

4.9.1 The design force considered for the scantlings of primary members, securing and supporting devices of side shell doors and stern doors are to be taken not less than:

(a) Design forces for securing or supporting devices of doors opening inwards:

External force:

$F_e = Ap_e + F_p$ kN

Internal force:

$F_i = F_o + 10W$ kN

(b) Design forces for securing or supporting devices of doors opening outwards:

External force:

$F_e = Ap_e$ kN

Internal force:

$P_i = P_o + 10W + F_p$ kN

(c) Design forces for primary members:

External force:

$F_e = Ap_e$ kN

Internal force:

$F_i = P_o + 10W$ kN

whichever is the greater.

The symbols used are defined as follows:

p_e = external sea pressure, in kN/m^2, determined at the centre of gravity of the door opening and is not to be taken less than:

for $Z_G < T$ 10 $(T - Z_G)$ + 25 kN/m^2
for $Z_G \geq T$ 25 kN/m^2
For stern doors, p_e is not to be taken less than:

p_{emin} = $0,6\,\lambda\, C_H \left(0,8 + 0,6\sqrt{L_R}\right)^2$ kN/m^2

T = summer draught, in metres

Z_G = height of the centre of area of the door, in metres, above the baseline

L_R = length of ship, but need not be taken greater than 200 m

λ = coefficient depending on the area where the ship is intended to be operated:

= 1 for sea-going ships with service area notation **SA1, SA2** and **SA3**

= 0,5 for ships operated in sheltered waters with service area notation **SA4**

C_H = 0,0125L_R for L_R < 80 m

= 1 for $L_R \geq$ 80 m

A = area, in m^2, of the door opening

W = weight of the door, in tonnes

F_p = total packing force, kN. When packing is fitted, the packing line pressure is to be specified, normally not to be taken less than 5 kN/m^2

F_o = the greater of F_c and 5,0A kN

F_c = accidental force, in kN, due to loose cargo, etc. to be uniformly distributed over the area A and not to be taken less than 300 kN. For small doors such as bunker doors and pilot doors, the value of P_c may be taken as zero, provided an additional structure such as an inner ramp is fitted, which is capable of protecting the door from accidental force due to loose items.

4.10 Design of securing and supporting devices

4.10.1 Securing devices and supporting devices are to be designed to withstand the forces given above using the following permissible stresses:

The terms 'securing device' and 'supporting device' are defined in *Vol 1, Pt 4, Ch 3, 3 Bow doors*

$$\tau = \frac{80}{k_s}\ \mathrm{N/mm^2}$$

$$\sigma = \frac{120}{k_s}\ \mathrm{N/mm^2}$$

$$\sigma_e = \frac{150}{k_s}\ \mathrm{N/mm^2}$$

4.10.2 The arrangement of securing and supporting devices is to be such that threaded bolts are not to carry support forces. The maximum tensile stress in way of threads of bolts, not carrying support forces, is not to exceed:

$$\frac{125}{k}\ \mathrm{N/mm^2}$$

4.10.3 For steel to steel bearings in securing and supporting devices, the normal bearing pressure is not to exceed 0,8σ_o, *see Vol 1, Pt 4, Ch 3, 4.1 Symbols 4.1.1* For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer's specification. The normal bearing pressure is to be calculated by dividing the design force by the projected bearing area.

4.10.4 The distribution of the reaction forces acting on the securing and supporting devices may require to be supported by direct calculations taking into account the flexibility of the hull structure and the actual position and stiffness of the supports. Small and/or flexible devices, such as cleats, intended to provide load compression of the packing material are not generally to be included in these calculations.

4.10.5 Only the active supporting and securing devices having an effective stiffness in the relevant direction are to be considered in the calculation of the reaction forces acting on the devices.

4.10.6 The number of securing and supporting devices is generally to be the minimum practicable whilst complying with *Vol 1, Pt 4, Ch 3, 4.6 Closing, securing and supporting of doors 4.6.3* and taking account of the available space in the hull for adequate support.

4.10.7 The arrangement of securing devices and supporting devices in way of these securing devices is to be designed with redundancy so that in the event of failure of any single securing or supporting device the remaining devices are capable of withstanding the reaction forces, without exceeding, by more than 20 per cent, the permissible stresses as defined in *Vol 1, Pt 4, Ch 3, 4.10 Design of securing and supporting devices 4.10.1*.

4.11 Operating and Maintenance Manual

4.11.1 An Operating and Maintenance Manual for the doors is to be provided on board. The manual is to contain the following information:

(a) main particulars and design drawings,

- special safety precautions;
- details of vessel, class and statutory certificates;

- equipment and design loading for ramps;
- key plan of equipment for doors and ramps;
- manufacturers' recommended testing for equipment; and
- a description of the following equipment: side doors; stern doors; central power pack; bridge panel; ramps leading down from the main deck; engine control room panel.

(b) service conditions:

- limiting heel and trim of the ship for loading/unloading;
- limiting heel and trim for door operations;
- operating instructions for doors and ramps and
- emergency operating instructions for doors and ramps.

(c) maintenance:

- schedule and extent of maintenance;
- troubleshooting and acceptable clearances; and
- manufacturers' maintenance procedures.

(d) register of inspections, including inspection of locking, securing and supporting devices, repairs and renewals.

4.11.2 The Manual is to be submitted for approval, and is to contain a note recommending that recorded inspections of the door supporting and securing devices be carried out by the ship’s staff at monthly intervals or following incidents that could result in damage, including heavy weather or contact in the region of the doors. Any damages recorded during such inspections are to be reported to LR.

4.11.3 Documented operating procedures for closing and securing the doors are to be kept on board and posted at an appropriate place.

■ *Section 5*
Movable decks, lifts, internal and external ramps

5.1 Classification

5.1.1 Where required by the LA Notation, *see Vol 1, Pt 1, Ch 2, 1.1 Framework of Classification 1.1.12* or specified by the Owner, movable decks will be included as a classification item. In such cases, all movable decks on board the ship are to comply with the requirements of this Section.

5.1.2 Plans showing the proposed scantlings and arrangements of the system are to be submitted.

5.1.3 The operating and securing equipment or machinery is to be in accordance with all specified standards.

5.2 Arrangements and design

5.2.1 Positive means of control are to be provided to secure decks, ramps and lifts in the raised and lowered position.

5.2.2 For steel to steel bearings in securing and supporting devices, the nominal bearing pressure calculated by dividing the design force by the projected bearing area is not to exceed 80 per cent of the yield stress of the bearing material. For other bearing materials, the permissible bearing pressure is to be determined according to the manufacturer’s specifications.

5.2.3 The arrangement of securing and supporting devices is to be such that threaded bolts do not carry support forces. The maximum tension in way of threads of steel bolts not carrying support forces is not to exceed $125/k$ N/mm^2.

5.3 Loading

5.3.1 Details of the deck, ramp or lift loading resulting from the proposed stowage arrangements of vehicles are to be supplied by the Shipbuilder. These details are to include the axle and wheel spacing, the wheel load, type of tyre and tyre print dimensions for the vehicles. For design purposes the wheel loading is to be taken as not less than 3,0 kN. *see Vol 1, Pt 4, Ch 3, 2 Vehicle decks and fixed ramps*.

5.3.2 Where it is proposed also to use the decks, ramps or lifts for general cargo, the design loadings are to be submitted for consideration.

5.3.3 The forces imposed on the decks, ramps or lifts are to take due account of the ship motion for all the conditions In which they will be operated, *see Vol 1, Pt 5, Ch 3, 6.2 Loads for ramps and lifts, Pra*

5.3.4 The scantlings and arrangements are to be not less than those required by the Rules for the supporting or surrounding structure in which the decks ramps or lifts are fitted. In general the end fixity of primary stiffening members is to be taken as simply supported. Local and secondary stiffening members may be either partially or fully fixed at their end connections dependent upon the proposed arrangement.

5.3.5 The buckling strength of primary members is to be verified as being adequate, *see Vol 1, Pt 6, Ch 2, 3 Buckling*

5.3.6 Decks, ramps or lifts and their supporting structure are to be designed for the maximum load that is to be carried; this may include loadings from emergency situations where they are specified by the Owner.

5.4 Movable decks

5.4.1 Movable decks are generally to be constructed as pontoons comprising a web structure with top decking. Other forms of construction will be individually considered.

5.4.2 The decks are to be efficiently supported, and hinges, pillars, chains or other means (or a combination of these) are to be designed on the basis of the imposed loads. Where supporting chains and fittings are required, they are to have a factor of safety of at least two on the proof load.

5.4.3 Where it is proposed to stow the pontoons on deck, when not in use, details of the proposals for racks, fittings, etc. are to be submitted for consideration.

5.4.4 Where wheeled vehicles are to be used, the supporting arrangements are to be such that the movement at the edge of one pontoon relative to the next does not exceed 50 mm during vehicle operations.

5.5 External deck ramps and lifts

5.5.1 In addition to the loading specified in *Vol 1, Pt 4, Ch 3, 5.3 Loading*, ramps and lifts are to be assessed using weather deck loading in the closed position, *see Vol 1, Pt 5, Ch 3, 5 Local design loads for decks and bulkheads*.

5.6 External shell ramps

5.6.1 In addition to the loading specified in *Vol 1, Pt 4, Ch 3, 5.3 Loading*, unprotected ramps are to be assessed using side shell loading in the closed position, *see Vol 1, Pt 5, Ch 3, 3 Loads on shell envelope*.

5.6.2 Scantlings of the primary members, securing and supporting devices of bow doors and inner doors are to be able to withstand the design loads defined in *Vol 1, Pt 4, Ch 3, 3.6 Design loads*. The shear, bending and equivalent stresses are not to exceed $80/k$ N/mm^2, $120/k$ N/mm^2 and $150/k$ N/mm^2 respectively.

5.7 Aircraft lifts

5.7.1 The aircraft lift platform deck alignment is to be provided by keeps at the flight deck and stops at the hangar deck.

5.7.2 If the ship has an underwater shock notation, latches are also to be provided at the flight and hangar deck levels to restrain the aircraft lift platform when stationary.

5.7.3 When transferring the aircraft or equipment to, or from, the lift platform with the keeps engaged the deflection of the platform edge is not to be greater than 25 mm.

■ *Section 1* Introduction

1.1 General

1.1.1 The global and local design loads and criteria detailed in this Part are to be used in conjunction with the formulae given in *Vol 1, Pt 6 Hull Construction in Steel* to determine the scantlings of naval ships as defined in *Vol 1, Pt 1 Regulations*.

1.1.2 When appropriate, the load and design criteria detailed in this Part are to be supplemented by direct calculation methods incorporating model test results and numerical analysis for novel designs. Full scale measurements may be required where considered necessary by Lloyd's Register (hereinafter referred to as 'LR').

1.1.3 Alternative methods of establishing the load and design criteria will be specially considered, provided that they are based on model tests, full scale measurements or generally accepted theories. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

■ *Section 2* Direct calculations

2.1 General

2.1.1 Direct calculations using hydrodynamic computer programs may be specifically required by the Rules. Also, they may be required for craft having novel design features, or may be submitted in support of alternative load and design criteria. LR may, when requested, undertake calculations on behalf of designers and make recommendations in regard to suitability of any required model tests.

2.2 Submission of direct calculations

2.2.1 In cases where direct calculations have been carried out the following supporting information is to be submitted as applicable:

(a) Reference to the direct calculation procedure and technical program used.
(b) Input data.
(c) A description of the direct calculation model.
(d) A summary of analysis parameters including environmental conditions, speeds and headings.
(e) Details of the weight distributions.
(f) A comprehensive summary of calculation results. Sample calculations are to be submitted where appropriate.

2.2.2 In general, all input data and output results are required to be submitted. In such cases, electronic transferral of data with agreed format may be used for submission.

2.2.3 The responsibility for error free specification and input of program data and the subsequent correct interpretation of output rests with the designer/Builder.

■ Section 3 Model experiments

3.1 General

3.1.1 LR may require model experiments and theoretical calculations to be carried out for novel or complex design concepts. It is advisable that details of all proposed model experiments and theoretical calculations are submitted to LR prior to commencement of the testing and analysis phases. The results of all such investigations are to be provided no later than when plans are submitted for approval, but preferably as early as possible.

3.1.2 Where model testing is undertaken, the following details are to be submitted:

(a) a summary of the model construction and its instrumentation, including calibration of instruments;
(b) a summary of the testing arrangements and procedures;
(c) a summary of the tank facilities and test equipment;
(d) details of the wave generation, response measurements, definitions and notations;
(e) details of data recording, data reduction and data analysis procedures;
(f) details of calibration procedures with theoretical computations; and
(g) tabulated and plotted output.

3.2 Model test matrix

3.2.1 Where model testing is undertaken, the minimum test matrix shown in *Table 1.3.1 Minimum test matrix* is required to be carried out.

Table 1.3.1 Minimum test matrix

Item	Test matrix
Sea state	Regular and irregular seas, using the wave environment details in *Vol 1, Pt 5, Ch 2 Environmental Conditions*.
Heading	Beam, head, stern and bow and stern quartering seas
Speed	Three speeds including zero and maximum service speeds
Wave Frequency	Six frequencies for regular seas

3.2.2 In addition to those quantities which are normally measured in a model experiment, the following data is to be obtained where appropriate:

(a) vertical accelerations at the LCG, bow and stern;
(b) acceleration loads due to heave, pitch and roll;
(c) vertical bending moment;
(d) bow impact pressures at representative operational forward speeds;
(e) oblique sea loads inducing horizontal bending moments and torsional moments.

3.2.3 The basis on which the parameters are chosen for investigation is to be submitted for approval at the earliest opportunity.

3.2.4 Results from open water model experiments and full scale measurements may be accepted, full details are to be submitted for appraisal.

■ Section 1 General

1.1 Introduction

1.1.1 This Chapter contains information regarding the environmental conditions to be applied in the derivation of loads that are to be used for the computation of the local and global design loads in *Vol 1, Pt 5, Ch 3 Local Design Loads* and *Vol 1, Pt 5, Ch 4 Global Design Loads*.

1.1.2 Environmental conditions include natural phenomena such as wind, wave and currents and also ice and thermal conditions.

1.1.3 The environmental conditions given here are derived from hindcast data, long term measurements and theoretical studies complemented with service experience.

1.1.4 Alternative methods of establishing the environmental conditions will be specially considered, provided that they are based on hindcast data, long term measurements, global and local environmental theoretical models, or similar techniques. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

1.1.5 In order that an assessment of the design requirements can be made, the following information is to be submitted:

(a) Service area notation required together with the required extent of the operational area.
(b) The wave environmental parameters for the design.
(c) Specification of the environmental conditions used for the design assessment.

1.2 Definitions and symbols

1.2.1 **Beaufort Number**. Beaufort Number is a measure of wind strength. The wind speed corresponding to each Beaufort number is shown in *Table 2.1.1 Wind data*.

1.2.2 **Sea state**. Sea state is an expression used to categorise wave conditions and is normally defined by a significant wave height and wave period, a suitable wave energy distribution may also be defined. A list of standard sea state definitions is shown in *Table 2.1.2 Sea state data*.

1.2.3 **Wave period**. References to wave period are to be taken as the zero crossing wave period, i.e. the average time interval between upward crossings of the mean value, unless otherwise stated.

Table 2.1.1 Wind data

Beaufort number	Wind speed range knots
0	0-1
1	1-3
2	4-6
3	7-10
4	11-16
5	17-21

6	22-27
7	28-33
8	34-40
9	41-47
10	48-55
11	56-63

Table 2.1.2 Sea state data

Sea State Number	Significant Wave height(m)		Sustained Wind Speed (Knots) (*See* Note 1)		Percentage probability of sea state	Modal Wave Period (sec)	
	Range	Mean	Range	Mean		Range (*see* Note 3)	Most Probable
0–1	0–0,1	0,05	0–6	3	0,7	–	–
2	0,1–0,5	0,3	7–10	8,5	6,8	3,3 –12,8	7,0
3	0,5 –1,25	0,88	11–16	13,5	23,7	5,0 –14,8	7,5
4	1,25 –2,5	1,88	17–21	19	27,8	6,1–15,2	8,8
5	2,5 –4	3,25	22–27	24,5	20,64	8,3 –15,5	9,7
6	4–6	5	28–47	37,5	13,15	9,8 –16,2	12,4
7	6–9	7,5	48–55	51,5	6,05	11,8 –18,5	15,0
8	9–14	11,5	56–63	59,5	1,11	14,2 –18,6	16,4
>8	>14	>14	>63	>63	0,05	18,0 –23,7	20,0

Note 1. Ambient wind sustained at 19,5 m above surface to generate fully-developed seas.

Note 2. To convert to another altitude, H_2, apply $V_2 = V_1 (H_2/19,5)^{(1/7)}$

Note 3. Minimum is 5 per cent and maximum is 95 per cent for periods given wave height range.

Note 4. The wave period shown here is the modal or peak period, T_p. The zero crossing period, T_z, may be derived by the expression $T_z = T_p/1,4$ for fully developed seas.

1.2.4 L_{WL} is defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*

■ *Section 2* **Wave environment**

2.1 General

2.1.1 Generally ships of Naval Ship Groups 1 and 2, **NS1** and **NS2**, *see Vol 1, Pt 1, Ch 2, 2.1 Applicable ship types* will be designed for unrestricted world-wide operation. Ships in group 3, **NS3**, may also be designed for world-wide operation but typically will be designed for more specific roles within clearly defined areas of operation, e.g. coastal patrol craft, landing craft, harbour vessels, tugs, etc.

2.1.2 The procedure for deriving the design factors and the wave environment used for the assessment of local and global loads is illustrated in *Figure 2.2.1 Procedure for the specification of environmental conditions*.

2.1.3 The following definitions are applicable:

Service area

(a) A service area refers to a collective group of sea areas. The service area specifies the limits of the ship's operational area.

Sea area

(a) A sea area is small area of the world's oceans for which statistical wave data has been collected, the sea areas are shown in *Figure 2.2.2 Sea areas*.

2.2 Service areas

2.2.1 All ships classed under the Rules will be assigned a service area notation **SA** followed by a number or letter, e.g. **SA1**.

2.2.2 The service area notations listed below are available. The definitive extents of the service areas are shown in *Figure 2.2.2 Sea areas* and *Table 2.2.3 Environmental wave data for individual sea area*. The chart shows the minimum service area requirement for operating in different areas of the world.

SA1 = Service Area 1 covers ships having unrestricted world-wide operation. Service area 1 includes operation in all other service areas.

SA2 = Service Area 2 is primarily intended to cover ships designed to operate in tropical and temperate regions, *see Vol 1, Pt 5, Ch 2, 2.2 Service areas 2.2.3*. This service area excludes operating in sea areas for which a **SA1** notation is required.

SA3 = Service Area 3 is primarily intended to cover ships designed to operate in tropical regions, *see Vol 1, Pt 5, Ch 2, 2.2 Service areas 2.2.3*. This service area excludes operating in sea areas for which a **SA1** or **SA2** notation is required.

SA4 = Service Area 4 covers ships designed to operate in Sheltered water, as defined in *Vol 1, Pt 1, Ch 2, 2.2 Definitions 2.2.13*. This service area excludes operating in sea areas for which a **SA1, SA2** or **SA3** notation is required.

SAR = Service Area Restricted covers ships that are designed to operate in a predetermined and contiguous area of operation, *see Vol 1, Pt 5, Ch 2, 2.2 Service areas 2.2.4*.

2.2.3 For all ships that are designed for specific areas of operation, the designer may take advantage of reduced wave loadings that are likely to be encountered. This covers all ships which are assigned a service area notation **SA2, SA3, SA4** or **SAR**.

2.2.4 For all cases where a **SAR** service area notation (Service Area Restricted) is required, the extents of the restricted area will be specified after the **SAR** service area notation. The service area factor, f_s, and the wave environment characteristics for the ship will be specially considered. Where the geographical limits of the intended service can be satisfied by a single or group of contiguous sea areas then the service area factor, f_s, and the wave environment characteristics may be derived using the methods given in *Vol 1, Pt 5, Ch 2, 2.4 Service Area factors* and *Vol 1, Pt 5, Ch 2, 2.5 Derivation of wave statistics for a combination of sea areas*.

2.2.5 Under normal circumstances, a ship which is assigned a service area notation **SA2, SA3, SA4** or **SAR** is to operate in solely the designated area and is not transit to other areas of the world, *see Vol 1, Pt 1, Ch 2, 3.5 Ship type notations*. Due allowance is to be made for the ship's trials, work-up period and delivery voyages in the assignment of a service area notation. However special consideration may be appropriate to these periods in order to ensure that the ship is not subjected to dynamic loads which might impair the structural working life of the ship.

2.2.6 The wave environmental data for service areas **SA1, SA2, SA3** and **SA4** are specified in *Vol 1, Pt 5, Ch 2, 2.3 Wave environment*.

2.2.7 It is the responsibility of the Owner to determine that the chosen Service Area, the service area factor, f_s, and the wave environment characteristics as defined in *Vol 1, Pt 5, Ch 2, 2.3 Wave environment* are appropriate for the intended areas of operation.

2.2.8 The allocation of a service area notation to a ship does not remove the responsibility of the Master or commanding officer to take suitable measures to avoid typhoon, hurricane and other extreme weather conditions, as appropriate.

2.2.9 The requirements for ships which are required to maintain station or operate in typhoon, hurricane and other extreme weather conditions will be specially considered.

2.3 Wave environment

2.3.1 The environmental wave data for each service area notation is given in *Table 2.2.1 Environmental wave data for each service area Table 2.2.4 Environmental wave data for each sea area* gives the environmental wave data for each individual sea area.

2.3.2 The definitions of wave height, wave period and wave period range given below are to be used in the determination of the environmental loads acting on the ship.

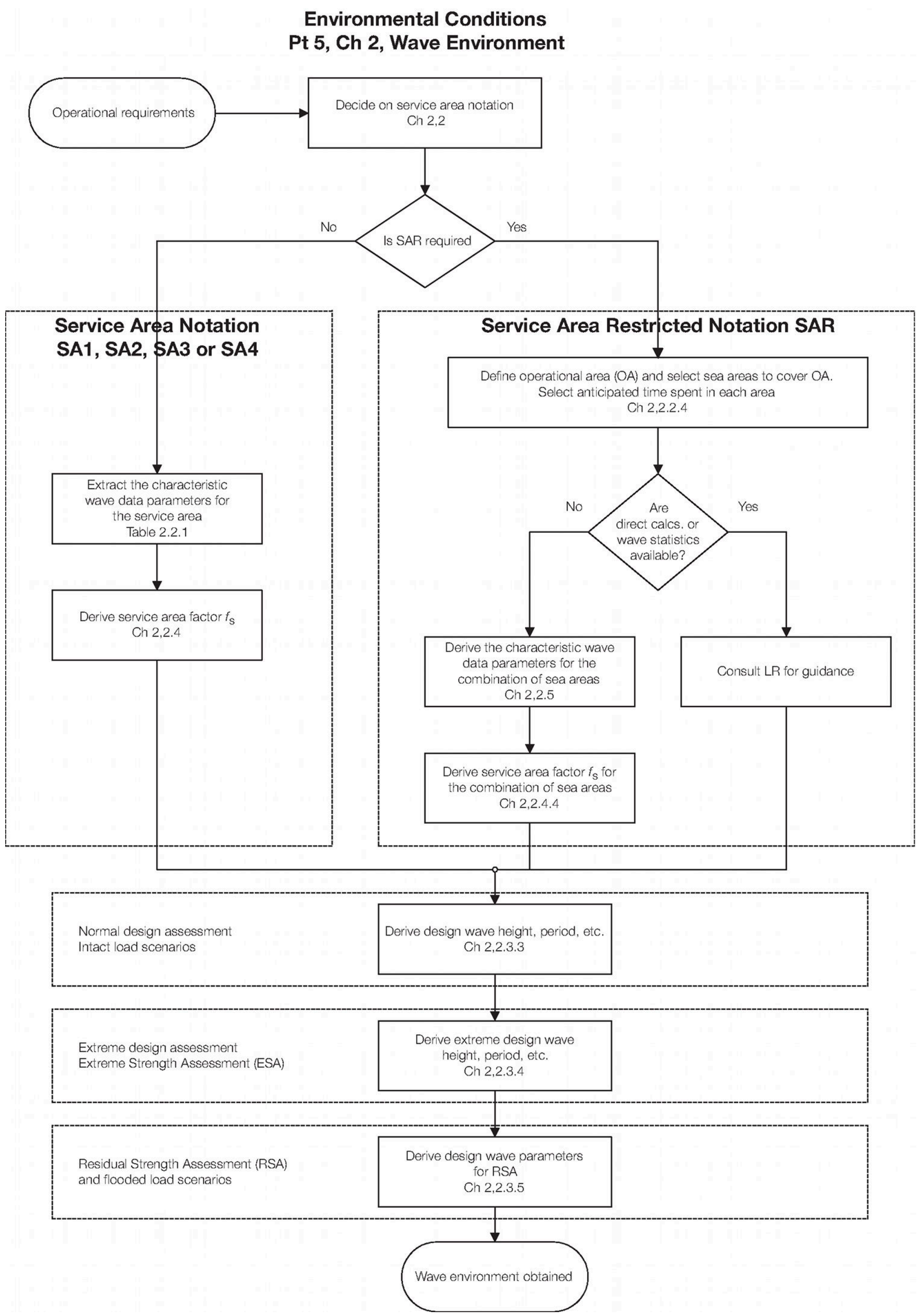


Figure 2.2.1 Procedure for the specification of environmental conditions

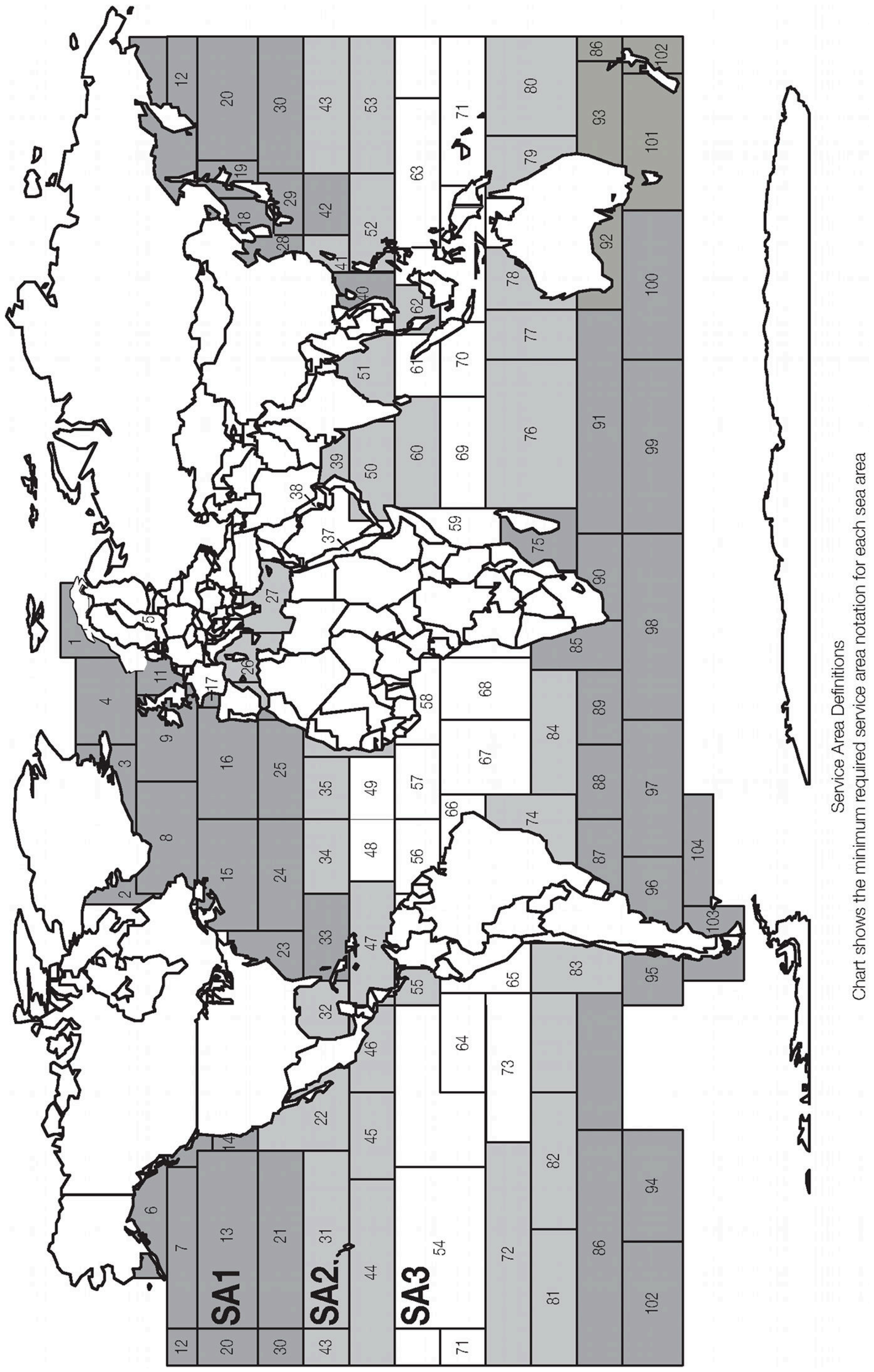


Figure 2.2.2 Sea areas

Table 2.2.1 Environmental wave data for each service area

Service Area Notation	Wave height for the service area, m	Mean wave period, seconds	Standard deviation of wave period, seconds	Extreme design wave height, m
	H_s	T_z	T_{sd}	H_x
SA1	5,5	8,0	1,7	18,5
SA2	4,0	7,0	1,7	13,5
SA3	3,6	6,8	1,7	9,5
SA4	2,5	6,0	1,5	6,0
SAR	To be specially considered			
Note *See* text and notes in *Table 2.2.4 Environmental wave data for each sea area* for definitions of all values.				

2.3.3 Wave environmental design criteria for normal design assessment. These design parameters have been used to derive the standard local and global environmental loadings in *Vol 1, Pt 5, Ch 3 Local Design Loads* and *Vol 1, Pt 5, Ch 4 Global Design Loads*. All direct calculations and model tests required to supplement these loads are to use these environmental loadings.

Design wave height, H_{dw}

(a) Average of the one hundredth highest observed wave heights for the service area. To be taken as:

$H_{dw} = 1{,}67 H_s$ m

Design wave period, T_{dw}

(a) Average zero crossing period of all sea states in the service area

$T_{dw} = T_z$ seconds

Standard deviation of wave period, T_{dsd}

(a) Standard deviation of the zero crossing periods for the service area

$T_{dsd} = T_{sd}$ seconds

Design wave period range, T_{drange}

(a) To be taken as the design wave period plus and minus 2 standard deviations of the zero crossing period, i.e.

T_{drange} is $T_{dw} - 2T_{dsd}$ to $T_{dw} + 2T_{dsd}$ seconds

H_s, T_z and T_{sd} are given in *Vol 1, Pt 5, Ch 2, 2.3 Wave environment 2.3.6*.

2.3.4 Wave environmental design criteria for extreme design analysis, **ESA** notations. These design parameters have been used to derive the global environmental loadings in *Vol 1, Pt 5, Ch 4 Global Design Loads* which are used for the extreme strength assessment notation. All direct calculations and model tests required to supplement these loads are to use these environmental loadings.

Extreme wave height, H_{xw}

(a) To be taken as the significant wave height that has a probability of 5 x 10^{-5} of being exceeded.

$H_{xw} = H_x$ m

Extreme wave period, T_{xw}

(a) To be taken as the design wave period plus one standard deviation

$T_{xw} = T_{dw} + T_{dsd}$ seconds

Extreme wave period range, T_{xrange}

(a) To be taken as the extreme design wave period plus and minus 1,5 standard deviations

T_{xrange} is $T_{xw} - 1{,}5T_{dsd}$ to $T_{xw} + 1{,}5T_{dsd}$ seconds

Duration of extreme storm

(a) It is to be assumed that extreme storm events are to persist for three hours.

T_{sd} and H_x are given in *Vol 1, Pt 5, Ch 2, 2.3 Wave environment 2.3.6*

T_{dw} and T_{dsd} is given in *Vol 1, Pt 5, Ch 2, 2.3 Wave environment 2.3.3*.

2.3.5 Wave environmental design criteria for residual strength analysis, **RSA** notations. These design parameters have been used to derive the global and local environmental loadings in *Vol 1, Pt 5, Ch 3 Local Design Loads* and *Vol 1, Pt 5, Ch 4 Global Design Loads* which are used for the residual strength assessment notation. All direct calculations and model tests required to supplement these loads are to use these environmental loadings.

Residual wave height, H_{rw}

(a) To be taken as the significant wave height that has a 20 per cent probability of being exceeded for the service area

$H_{rw} = 0{,}90H_s$ m

Residual wave period, T_{rw}

(a) To be taken as the standard design wave period

$T_{dw} = T_z$ seconds

Residual wave period range, T_{rrange}

(a) To be taken as the standard design wave period range

$T_{rrange} = T_{drange}$ seconds

Duration of sea state

(a) It is to be assumed that the duration of sea states of this magnitude is 12 hours.

H_s and T_z are given in *Vol 1, Pt 5, Ch 2, 2.3 Wave environment 2.3.6*

T_{drange} is given in *Vol 1, Pt 5, Ch 2, 2.3 Wave environment 2.3.3*.

2.3.6 The parameters used in above equations are given in *Table 2.2.1 Environmental wave data for each service area* for service area notations **SA1, SA2, SA3** and **SA4**. For the restricted service area notation **SAR**, the values of H_s, T_z, T_{sd} and H_x will need to be derived, *see Vol 1, Pt 5, Ch 2, 2.5 Derivation of wave statistics for a combination of sea areas*.

2.4 Service Area factors

2.4.1 The service area factor, f_s, is used to derive the global hull girder loads in *Vol 1, Pt 5, Ch 4 Global Design Loads*. The service area factor applicable for Service Area notations **SA1, SA2, SA3** and **SA4** is given by:

$$f_s = (f_1 + f_2 (L_{WL} - 100) /1000) f_{sl}$$

where

(a) f_s is to have a minimum value of 0,5 and normally a maximum value of 1,0 and is to be rounded up to the nearest 0,05

f_{sl} is the service life factor as defined in *Vol 1, Pt 5, Ch 2, 2.4 Service Area factors 2.4.2*

f_1 and f_2 are given in *Table 2.2.2 Environmental wave data for service area*

L_{WL} is defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*.

2.4.2 The service life factor, f_{sl}, is based on a ship's operational life. This factor may need to be increased for service lives which are predicted to require significantly more wave encounters. The service life factor is to be taken as follows:

$$f_{sl} = 1{,}0 \text{ for } 1 \times 10^8 \text{ wave encounters (20 years)}$$
$$= 1{,}010 \text{ for } 1{,}25 \times 10^8 \text{ wave encounters (25 years)}$$
$$= 1{,}019 \text{ for } 1{,}5 \times 10^8 \text{ wave encounters (30 years)}$$

Table 2.2.2 Environmental wave data for service area

Service Area Notation	Intercept factor f_1	Slope factor f_2
SA1	1,00	0,00
SA2	0,93	–1,15
SA3	0,70	–1,00
SA4	0,50	0,00
SAR	To be specially considered	

2.4.3 For unrestricted sea-going service, i.e. service area notation **SA1**, the service area factor is to be taken as 1,0.

2.4.4 Alternatively the service area factor may be derived by direct calculation of the long term hull girder loads, *see Vol 1, Pt 5, Ch 4, 1.3 Direct calculation procedures 1.3.1*

2.4.5 For restricted Service Area Notation **SAR** the service area factor is to be derived by combining the service areas factors for each sea area using the following formula:

$$f_s = \ln\left(\sum_{i=1}^{n} P_i e^{f_{si}}\right)$$

where

$$f_{si} = f_{1i} + f_{2i}(L_{WL} - 100)/1000$$

f_{1i} and f_{2i} are the individual sea area factors given in *Table 2.2.3 Environmental wave data for individual sea area*

$$e = 2{,}7183$$

ln ( ) is the natural log

P_i is defined in *Vol 1, Pt 5, Ch 2, 2.5 Derivation of wave statistics for a combination of sea areas 2.5.3*

2.5 Derivation of wave statistics for a combination of sea areas

2.5.1 For the **SAR** restricted service area notation, it is necessary to derive the environmental wave data for the required area of operation. This data may be determined using statistical methods as specified in *Vol 1, Pt 5, Ch 2, 2.6 Direct calculations* or using the information given in this Section.

2.5.2 The following formulae may be used to derive the design wave statistics for a ship designed to operate with a particular service area restriction. These formulae enable the environmental wave data from a set of individual sea areas to be combined to give the appropriate design wave statistics for the **SAR** restricted service area notation, *see also Vol 1, Pt 5, Ch 2, 2.2 Service areas*.

2.5.3 The environmental wave data for each sea area is given in *Table 2.2.4 Environmental wave data for each sea area* The extents of each sea area are shown in *Figure 2.2.2 Sea areas*

Wave height, H_s

H_s = weighted average of the wave height for all sea areas plus one standard deviation

$$= H_{sm} + \sqrt{\sum_{i=1}^{n} P_i (H_{si} - H_{sm})^2}\ \mathrm{m}$$

where

$$H_{sm} = \sum_{i=1}^{n} P_i H_{si}\ \mathrm{m}$$

Design wave period, T_{dw}

T_{dw} = weighted average of the wave period for all sea areas

$$= \sum_{i=1}^{n} P_i T_{zi} \text{seconds}$$

Standard deviation of wave period, T_{sd}

T_{sd} = weighted average of the standard deviation for all sea areas about the combined design wave period, T_{dw}

$$= \sqrt{\sum_{i=1}^{n} P_i \left(T_{sdi}^2 + \left(T_{dw} - T_{zi}\right)^2\right)} \; seconds$$

Extreme wave height, H_x

H_x = weighted average of the extreme wave height for all sea areas plus one standard deviation

$$= H_{xm} + \sqrt{\sum_{i=1}^{n} P_i \left(H_{xi} - H_{xm}\right)^2} \text{ m}$$

where

$$H_{xm} = \sum_{i=1}^{n} P_i H_{xi} \text{m}$$

N = is the number of sea areas

i = is the sea area index reference

P_i = is the probability of the ship operating in sea area i, i.e. the percentage of time, expressed as a probability value

H_{si} = is the appropriate sea area wave height value for sea area i

H_{xi} = is the appropriate extreme wave height value for sea area i

T_{zi} = is the appropriate zero crossing period for sea area i

T_{sdi} = is the appropriate standard deviation for sea area i

2.5.4 The designer/Builder is to supply full details of the **SAR** notation required together with full supporting calculations. All transit voyages and ship work-up/trial periods should be included in the list of sea areas if their inclusion results in a more severe wave environment, *see also Vol 1, Pt 5, Ch 2, 2.2 Service areas 2.2.5*

2.6 Direct calculations

2.6.1 The wave environmental parameters may be derived by direct calculation using long term statistical wave data for the selected area(s) of operation based on hindcast data or similar analysis. This data is to represent accurately the sea environment in the intended area of operation over a long period and enable sound long term and extreme short term statistics to be derived. Depending on the area of operation, due account is to be taken of typhoon, hurricane and other seasonal extremes, *see also Vol 1, Pt 5, Ch 2, 2.2 Service areas 2.2.8*

Table 2.2.3 Environmental wave data for individual sea area

Sea Area No.	Minimum service area notation required to operate in this sea area	Intercept factor f_{1i}	Slope factor f_{2i}	Sea Area No.	Minimum service area notation required to operate in this sea area	Intercept factor f_{1i}	Slope factor f_{2i}
1	SA1	1,13	–1,97	51	SA2	0,82	–1,89
2	SA2	0,94	–1,81	52	SA2	0,87	–1,43
3	SA1	1,13	–1,97	53	SA2	0,74	–0,84
4	SA1	1,01	–1,01	54	SA3	0,62	–0,65
5	SA3	0,72	–1,85	55	SA2	0,78	–0,97
6	SA1	1,08	–1,33	56	SA3	0,63	–0,71
7	SA1	0,89	–0,16	57	SA3	0,56	–0,77
8	SA1	0,98	0,17	58	SA3	0,57	–1,13
9	SA1	1,00	0,02	59	SA3	0,69	–1,15
10	SA1	1,11	–1,80	60	SA2	0,87	–1,43
11	SA1	1,18	–2,56	61	SA3	0,69	–1,15
12	SA1	1,19	–1,44	62	SA2	0,85	–2,13
13	SA1	0,96	–0,48	63	SA3	0,69	–1,31
14	SA1	0,96	–0,81	64	SA3	0,59	–0,55
15	SA1	1,01	–0,34	65	SA3	0,55	–0,43
16	SA1	1,00	0,02	66	SA3	0,59	–0,55
17	SA1	1,03	–0,64	67	SA3	0,63	–0,71
18	SA1	1,11	–3,45	68	SA3	0,65	–0,83
19	SA1	1,10	–1,52	69	SA3	0,68	–0,97
20	SA1	1,10	–0,83	70	SA3	0,67	–0,58
21	SA1	0,88	–0,53	71	SA3	0,69	–1,50
22	SA2	0,80	–1,29	72	SA2	0,63	–0,32
23	SA1	1,00	–1,65	73	SA3	0,64	–0,33
24	SA1	1,01	–0,50	74	SA2	0,74	–0,84
25	SA1	0,90	–0,42	75	SA1	0,85	–0,65
26	SA2	0,98	–2,43	76	SA2	0,77	–0,19
27	SA2	0,98	–2,43	77	SA2	0,79	–0,20
28	SA2	0,98	–2,43	78	SA2	0,86	–0,98
29	SA1	1,06	–2,05	79	SA2	0,87	–1,42
30	SA1	1,01	–0,50	80	SA2	0,78	–0,56
31	SA2	0,74	–0,44	81	SA2	0,79	–0,20
32	SA2	0,82	–1,89	82	SA2	0,74	–0,44

33	SA1	0,75	–1,01	83	SA2	0,75	–0,58
34	SA2	0,78	–0,70	84	SA2	0,73	–0,69
35	SA2	0,73	–0,76	85	SA1	0,80	–0,15
36	SA2	0,75	–1,16	86	SA1	0,89	–0,26
37	SA3	0,72	–1,85	87	SA1	0,91	–0,51
38	SA3	0,69	–2,13	88	SA1	0,89	–0,16
39	SA2	0,85	–2,14	89	SA1	0,98	–0,08
40	SA1	1,05	–1,97	90	SA1	0,98	–0,08
41	SA1	1,00	–1,65	91	SA1	0,98	–0,08
42	SA2	0,98	–1,31	92	SA1	0,90	0,09
43	SA2	0,78	–0,54	93	SA1	0,90	–0,32
44	SA2	0,78	–0,54	94	SA1	0,98	0,31
45	SA2	0,64	–0,34	95	SA1	0,89	–0,16
46	SA2	0,75	–1,22	96	SA1	1,00	–0,91
47	SA2	0,75	–1,01	97	SA1	0,98	0,16
48	SA3	0,65	–0,78	98	SA1	0,89	0,21
49	SA3	0,68	–0,94	99	SA1	0,98	0,30
50	SA2	1,09	–2,70	100	SA1	1,03	0,52
				101	SA1	0,98	–0,18
				102	SA1	0,89	–0,16
				103	SA1	1,06	–0,23
				104	SA1	0,89	-0,26

2.6.2 The derivation of the wave environmental parameters is to be in accordance with the data specification and methods given in *Vol 1, Pt 5, Ch 2, 2.3 Wave environment*. The areas used for the direct calculation will then be specified after the **SAR** service area restriction notation.

Table 2.2.4 Environmental wave data for each sea area

Sea Area No.	Sea area wave height in metres	Mean wave period in seconds	Standard deviation of wave period in seconds	Extreme design wave height in metres	Sea Area No.	Sea area wave height in metres	Mean wave period in seconds	Standard deviation of wave period seconds	Extreme design wave height in metres
	H_{si}	T_{zi}	T_{sdi}	H_{xi}		H_{si}	T_{zi}	T_{sdi}	H_{xi}
1	3,6	6,4	1,3	16,9	53	3,7	7,5	1,5	10,0
2	3,0	6,2	1,3	12,5	54	3,5	7,7	1,5	8,9
3	4,3	7,5	1,4	17,6	55	2,5	6,2	1,3	7,4
4	4,4	7,4	1,4	16,2	56	3,4	7,4	1,5	8,6
5	2,5	5,2	1,1	8,6	57	3,1	7,1	1,5	7,8
6	4,2	7,4	1,4	15,6	58	2,5	6,1	1,3	7,1

7	5,0	8,4	1,5	15,4	59	2,9	6,3	1,3	9,2
8	5,5	8,6	1,5	18,4	60	3,0	6,3	1,3	11,5
9	5,3	8,5	1,5	18,2	61	3,0	6,5	1,3	9,0
10	3,7	6,7	1,3	15,8	62	2,5	5,5	1,2	11,0
11	3,4	6,1	1,2	17,0	63	2,7	6,2	1,3	8,4
12	5,0	7,8	1,4	18,3	64	3,4	7,5	1,5	8,2
13	4,8	8,3	1,5	16,2	65	2,9	7,1	1,5	8,2
14	4,0	7,7	1,5	14,5	66	3,4	7,3	1,5	8,1
15	4,7	8,0	1,4	17,9	67	3,5	7,4	1,5	8,9
16	5,2	8,4	1,5	19,2	68	3,5	7,2	1,4	8,7
17	4,3	7,8	1,4	18,3	69	3,2	7,2	1,5	9,2
18	2,7	4,9	1,0	14,5	70	3,4	7,6	1,5	9,7
19	3,8	7,0	1,4	17,5	71	2,5	5,9	1,3	8,3
20	4,8	8,0	1,4	18,4	72	3,6	7,7	1,5	9,5
21	4,4	8,1	1,5	14,0	73	4,0	8,0	1,5	9,4
22	3,3	7,0	1,4	10,7	74	3,3	7,2	1,4	10,6
23	3,4	6,5	1,3	15,2	75	3,9	7,8	1,5	13,0
24	4,6	8,0	1,5	17,4	76	4,4	8,2	1,5	12,5
25	4,4	8,1	1,5	14,5	77	4,6	8,3	1,5	12,6
26	2,7	5,5	1,2	13,6	78	3,8	7,6	1,5	12,0
27	2,6	5,6	1,2	13,2	79	3,3	6,5	1,3	11,2
28	2,8	5,5	1,1	12,4	80	3,7	7,7	1,5	12,2
29	3,4	6,3	1,3	15,5	81	4,4	8,2	1,5	12,7
30	4,7	8,2	1,5	16,8	82	4,1	8,0	1,5	11,3
31	3,8	7,8	1,5	11,5	83	3,8	7,8	1,5	11,2
32	2,8	5,8	1,2	10,0	84	4,3	8,2	1,5	10,8
33	3,2	6,8	1,4	11,5	85	4,9	8,4	1,5	13,3
34	3,6	7,6	1,5	11,5	86	4,6	8,2	1,5	15,7
35	3,9	7,9	1,5	10,3	87	3,8	7,7	1,5	16,8
36	3,3	6,9	1,4	9,5	88	5,0	8,5	1,5	15,3
37	2,3	5,1	1,1	8,5	89	4,8	8,3	1,5	18,2
38	1,8	4,5	0,9	8,3	90	5,2	8,5	1,5	17,9
39	2,5	5,2	1,1	10,5	91	5,4	8,6	1,5	17,7
40	3,5	6,3	1,2	13,4	92	5,2	8,5	1,5	16,7
41	3,7	6,6	1,3	14,0	93	4,2	8,0	1,5	15,3
42	3,6	6,9	1,4	15,2	94	6,0	8,9	1,4	17,7

43	4,1	7,9	1,5	12,1	95	5,5	8,7	1,5	14,6
44	4,0	8,0	1,5	10,1	96	4,0	7,5	1,4	16,9
45	3,7	7,8	1,5	9,5	97	5,6	8,7	1,5	17,3
46	2,8	6,4	1,3	10,7	98	5,6	8,7	1,5	16,7
47	3,4	6,6	1,3	10,0	99	6,1	9,0	1,4	18,0
48	3,6	7,6	1,5	9,2	100	6,0	8,9	1,4	20,1
49	3,5	7,3	1,4	9,0	101	4,9	8,4	1,5	17,1
50	3,1	5,8	1,2	14,1	102	4,8	8,3	1,5	16,5
51	2,7	5,8	1,2	10,4	103	5,3	8,5	1,5	18,2
52	3,2	6,5	1,3	12,2	104	4,7	8,2	1,5	16,6

Note 1. The sea area wave height H_{si} and wave zero crossing period, T_{zi}, are based on the annual, all directions wave data scatter diagram.

Note 2. The sea area wave height H_{si} is the average of the one third highest observed (or significant) wave heights in the wave scatter diagram.

Note 3. The T_{zi} and standard deviation of T_{sdi} are derived using all wave heights in the wave data scatter diagram.

Note 4. The extreme design wave height, H_{xi}, is based on a Gumbel projection using the following data set definition:
A wave data scatter diagram based on integer parts per ten thousand. *(Note using a higher precision scatter diagram will result in a higher estimate of extreme wave height)*. Probability of exceedence of 5 x10^{-5}, roughly equivalent to 6,5 years continuously at sea in each sea area.

Note 5. The values of H_{si}, T_{zi}, and T_{sdi} were derived from the data set used for the extreme wave height.

■ *Section 3* **Air environment**

3.1 Wind speed

3.1.1 For design purposes a wind speed of 40 m/s is to be assumed.

3.2 Design air temperature

3.2.1 The design air temperature is to be taken as 2°C lower than the lowest mean daily average air temperature in the area of operation:

where

Mean = statistical mean over a minimum of 20 years (MDHT)

Average = average during one day and one night (MDAT)

Lowest = lowest during the year (MDLT).

Figure 2.3.1 Design air temperature shows the definition graphically.

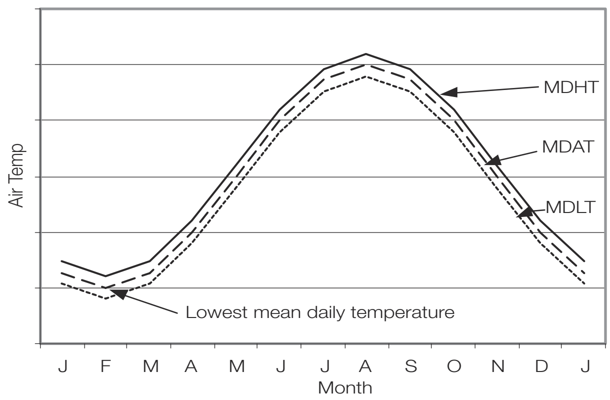


Figure 2.3.1 Design air temperature

■ *Section 4*
Guidance for ice environment

4.1 General

4.1.1 This section is intended to give guidance on the selection of a suitable ice class notation for the operation of naval ships in Arctic and Antarctic regions.

4.1.2 It is the responsibility of the Owner to determine which notation is most suitable for their requirements. Ultimately the responsibility rests with the commanding officer and their assessment of the ice and temperature conditions at the time.

4.1.3 The documentation supplied to the ship is to contain the ice class notation adopted, any operation limits for the ship and guidance on the type of ice that can be navigated for the nominated ice class.

4.2 Definitions

4.2.1 The World Meteorological Organisation's, WMO, definitions for sea ice thickness are given in *Table 2.4.1 WMO definition of ice conditions*.

Table 2.4.1 WMO definition of ice conditions

Ice conditions	Ice thickness
Medium first year	1,2 m
Thin first year, second stage	0,7 m
Thin first year, first stage	0,5 m
Grey-white	0,3 m
Grey	0,15 m

4.2.2 *Table 2.4.2 Comparison ice standards* defines the ice classes in relation to the Rules and the equivalent Internationally recognised Standards.

Table 2.4.2 Comparison ice standards

Lloyd's Register class notation	Finnish-Swedish Ice-Due class	Canadian type
1AS	IA Super	A
1A	IA	B
1B	IB	C
1C	IC	D
1D	ID	–
none	none	E

4.2.3 Extended periods are defined as those that involve the vessel remaining in air temperatures below 0°C for more than one week.

4.3 Application

4.3.1 For naval ships intended for extended periods of operation in Arctic and Antarctic areas the suggested ice class is **1C**. For these operational limits, the materials used for hull construction are to be in accordance with *Vol 1, Pt 6, Ch 6, 2 Materials*. If a higher ice class is proposed, material requirements are to be specially considered using a specified design air temperature as defined in *Vol 1, Pt 5, Ch 2, 3.2 Design air temperature*.

4.3.2 For naval ships required to operate in multi year ice as defined by the Ice breaker region in *Figure 2.4.1 Ice limits Arctic Winter* without an ice breaker escort, the requirements for ice class will be specially considered. Material requirements are to be in accordance with *Vol 1, Pt 6, Ch 6, 2 Materials* using a specified design air temperature as defined in *Vol 1, Pt 5, Ch 2, 3.2 Design air temperature*.

4.3.3 The variable nature of ice conditions is such that the average limits of the conditions are not easily defined. However, it is possible to plot the probable limits of the ice flows and the ice edge for each season. Operation with Ice Class **1C** may be possible up to 150 nm inside the 7/10 region shown depending on the severity of the winter. Operation with Ice Class **1A** may be possible up to 150 nm inside the medium first year ice shown depending on the severity of the winter. Operation up to the multi year ice is possible most years with Ice Class **1AS**.

4.3.4 Operation in the region between 7/10 and 1/10 in the arctic is possible with due care for ships with no ice class. For ships operating for extended periods in these areas it will be necessary to specify and design for a minimum temperature for the hull materials. To cover all situations for a non-ice class ship, the material requirements of *Vol 1, Pt 6, Ch 6, 2 Materials* are recommended.

4.4 Ice Class notations

4.4.1 Where the requirements of *Vol 3, Pt 1, Ch 1 Ice Navigation - First-Year Ice Conditions* are complied with, the ship will be eligible for a special features notation as defined in *Vol 1, Pt 1, Ch 2, 3.9 Machinery and Engineering Systems notations*

4.5 National Authority requirements

4.5.1 Certain areas of operation may require compliance or demonstration of equivalence with National Authority requirements. *Table 2.4.2 Comparison ice standards* gives the equivalence of National Authority requirements.

4.5.2 The standards of ice strengthening required by the Rules have been accepted by the Finnish and Swedish Boards of Navigation as being such as to warrant assignment of the Ice-Due Classes given in *Table 2.4.2 Comparison ice standards*. For definition of Ice-Due Classes, *see Finnish-Swedish Ice Class Rules, 1985*.

4.5.3 Ships intending to navigate in the Canadian Arctic must comply with the Canadian Arctic Shipping Pollution Prevention Regulations established by the Consolidated Regulations of Canada, 1978, Chapter 353, in respect of which LR is authorised to issue Arctic Pollution Prevention Certificates.

4.5.4 The Canadian Arctic areas have been divided into zones relative to the severity of the ice conditions experienced and, in addition to geographic boundaries, each zone has seasonal limits affecting the necessary ice class notation required to permit

operations at a particular time of year. It is the responsibility of the Owner to determine which notation is most suitable for their requirements.

4.6 Ice accretion

4.6.1 For ships intended to operate for extended periods in Arctic or Antarctic the build up of ice on exposed surfaces is to be considered. *See Vol 1, Pt 5, Ch 3, 7 Ice loads* and *Vol 1, Pt 5, Ch 4, 2 Still water global loads*.

4.6.2 As a minimum a full icing allowance is to be applied to vessels operating in the following areas, *see Figure 2.4.5 Ice accretion limits Arctic*:

- The area north of latitude 65°30'N, between longitude 28°W and the West coast of Iceland; north of the north coast of Iceland; north of the rhumb line running from latitude 66°N, longitude 15°W to latitude 73°30'N, longitude 15°E, north of latitude 73°30'N between longitude 15°E and 35°E, and east of longitude 35°E, as well as north of latitude 56°N in the Baltic Sea.
- The area north of latitude 43°N bounded in the west by the North American coast and the east by the rhumb line running from latitude 43°N, longitude 48°W to latitude 63°N, longitude 28°W and thence along longitude 28°W.
- All sea areas north of the North American continent west of the areas defined in subparagraphs above.
- The Bering and Okhotsk Seas and the Tartary Strait during the icing season.
- South of latitude 60°S.

4.6.3 A full icing allowance is defined as an additional pressure of 1 kN/m^2 (100 mm of ice) applied to all exposed horizontal or near horizontal surfaces and 0,25 kN/m^2 (25 mm of ice) applied to all exposed vertical surfaces. The volumetric centre of the ice is to be taken as that of an equivalent head of water. The density of the ice is assumed to be 1000 kg/m^3.

4.6.4 As a minimum a half icing allowance is to be applied to vessels operating in the winter seasonal areas as defined in the international Load Line Convention.

4.6.5 A half icing allowance is defined as an additional pressure of 0,5 kN/m^2 (50 mm of ice) applied to all exposed horizontal or near horizontal surfaces and 0,18 kN/m^2 (18 mm of ice) applied to all exposed vertical surfaces. The volumetric centre of the ice is to be taken as that of an equivalent head of water. The density of the ice is assumed to be 1000 kg/m^3.

4.6.6 The effects on stability of ice accretion are to be assessed in accordance with the specified subdivision and stability standard.

4.6.7 Where alternative icing allowances are specified and these allowances exceed that defined in *Vol 1, Pt 5, Ch 2, 4.6 Ice accretion 4.6.3* and *Vol 1, Pt 5, Ch 2, 4.6 Ice accretion 4.6.5* for the appropriate operational areas, these allowances shall be used in the assessment of the local and global structure.

4.7 Ice conditions

4.7.1 Charts and images for the current and recent ice conditions in all areas of the world plus information on icebergs can be found from the National Ice Centre on the world wide web at

(a) http//www.natice.noaa.gov/.

Information is supplied by regular assessment and survey by the naval ice centres patrols.

4.7.2 Daily ice information and consultation is available from the Canadian ice service which is part of the Canadian department of the environment. Their web site can be found at

(a) http// www.ice-glaces.ec.gc.ca.

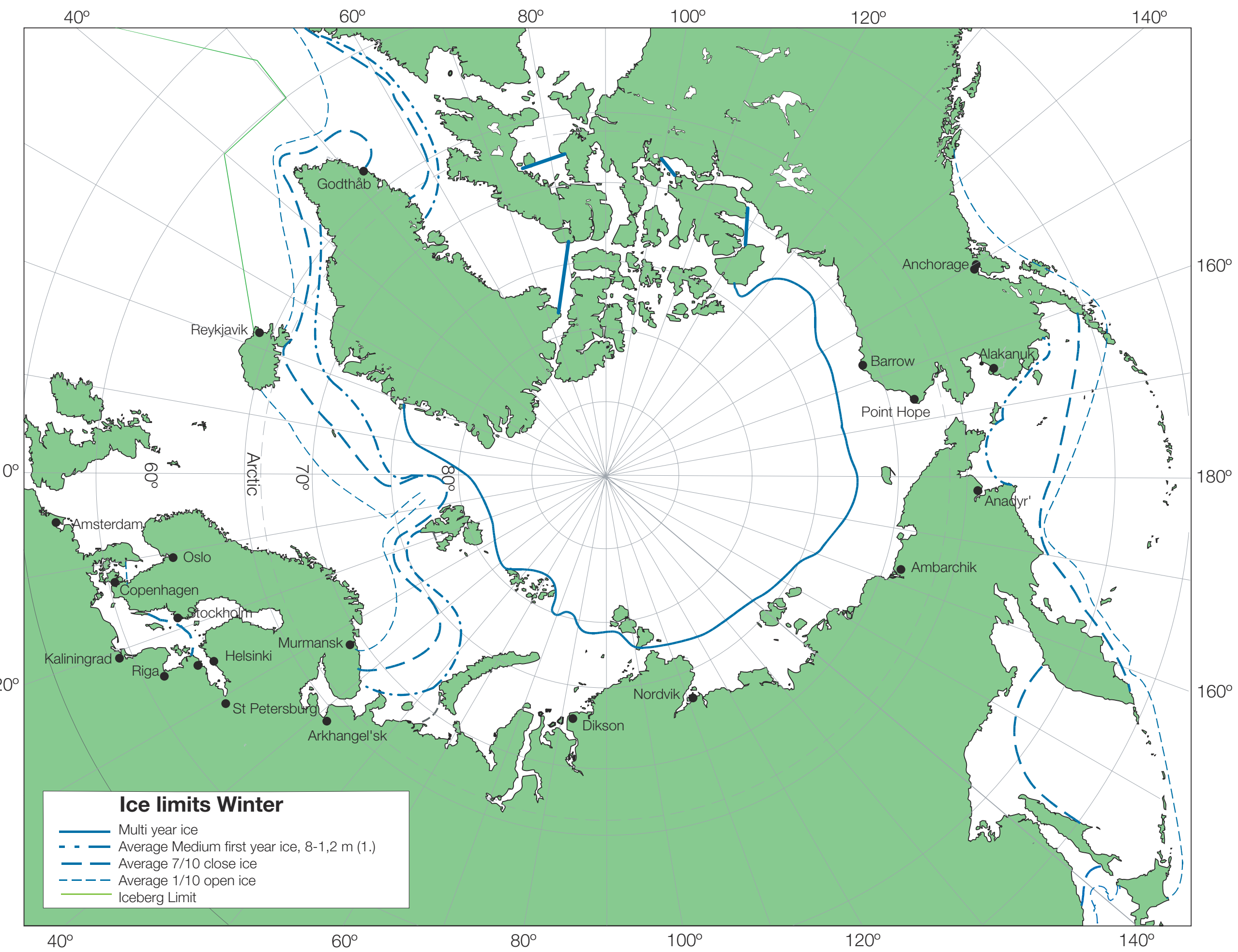


Figure 2.4.1 Ice limits Arctic Winter

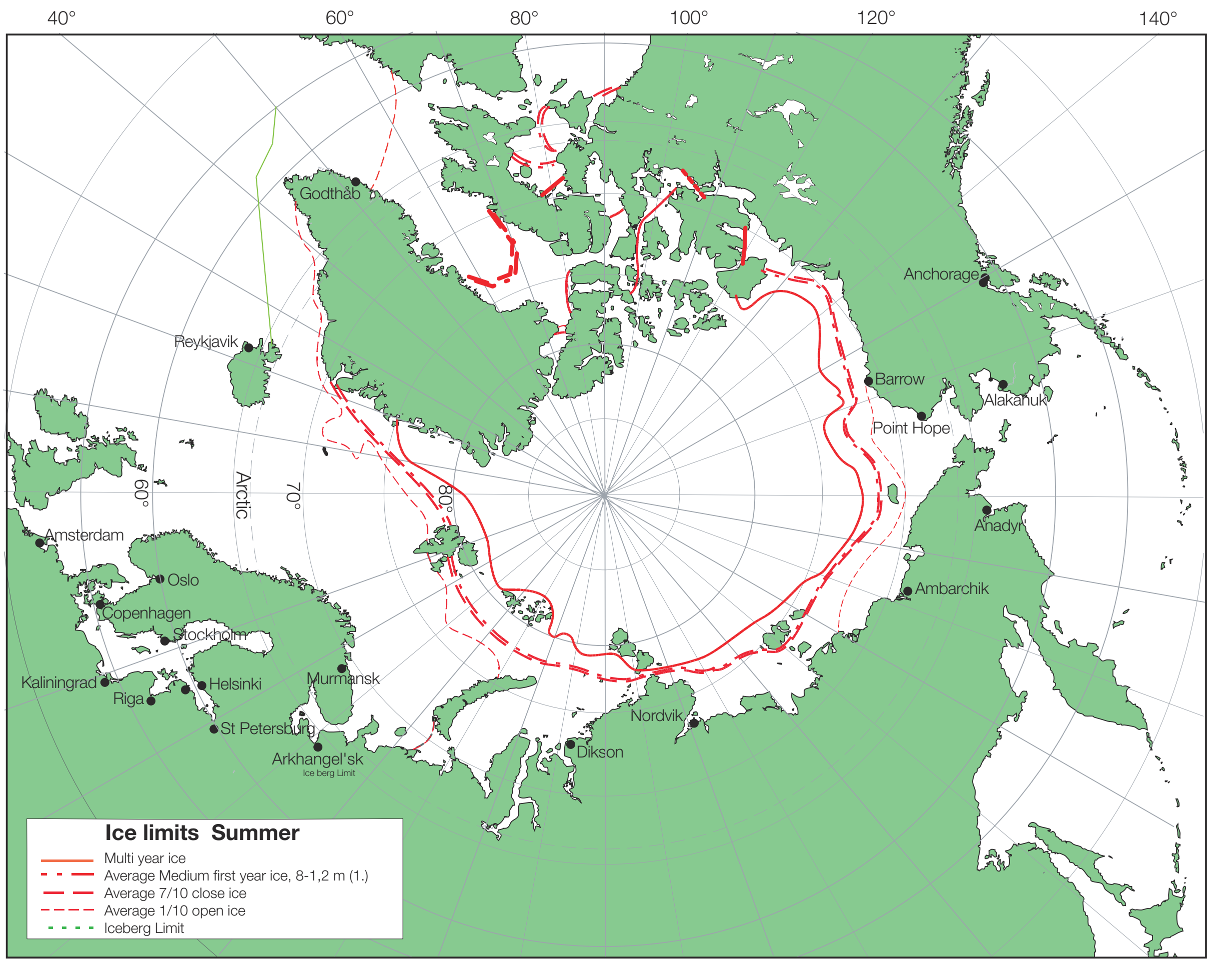


Figure 2.4.2 Ice limits Arctic Summer

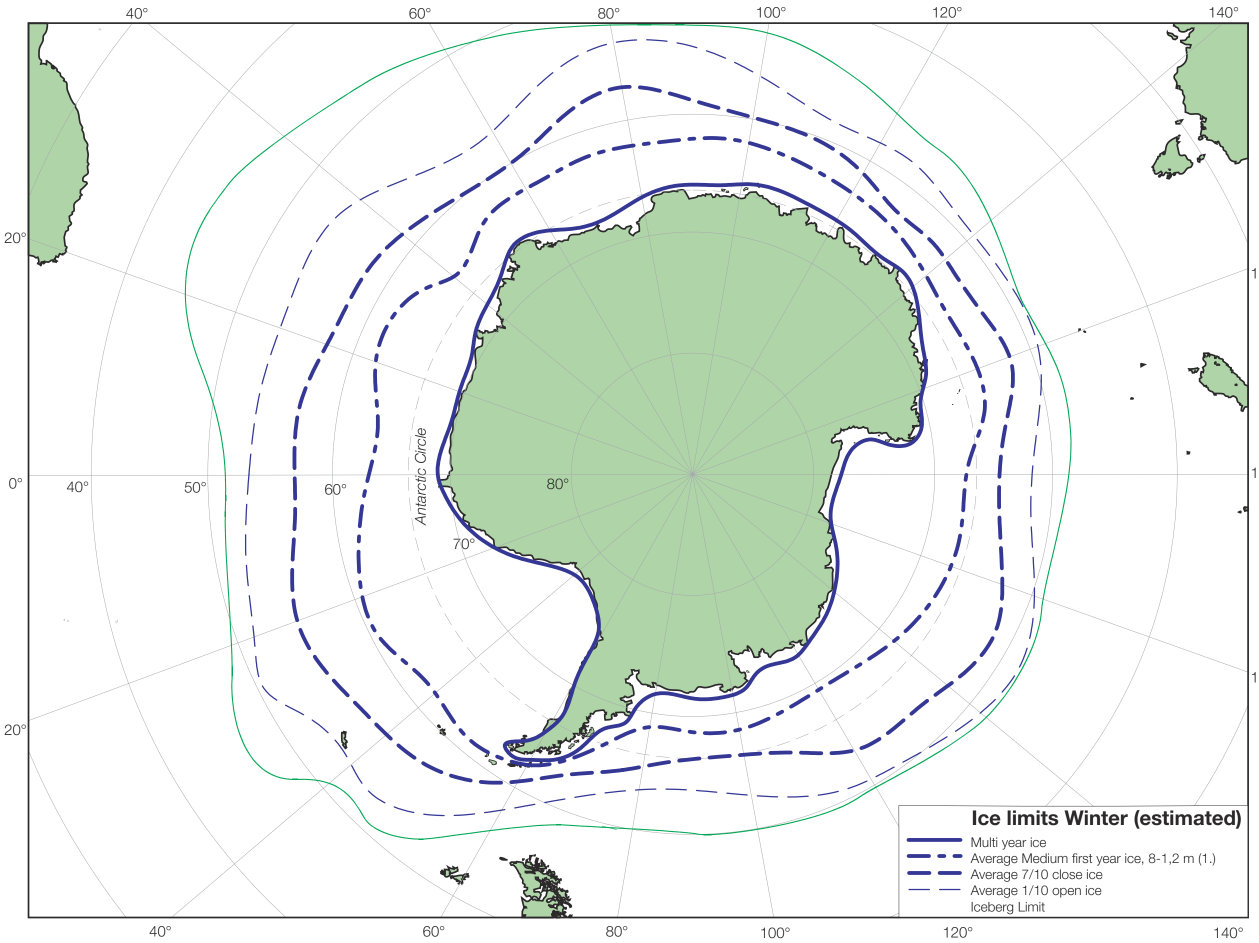


Figure 2.4.3 Ice limits Antarctica Winter

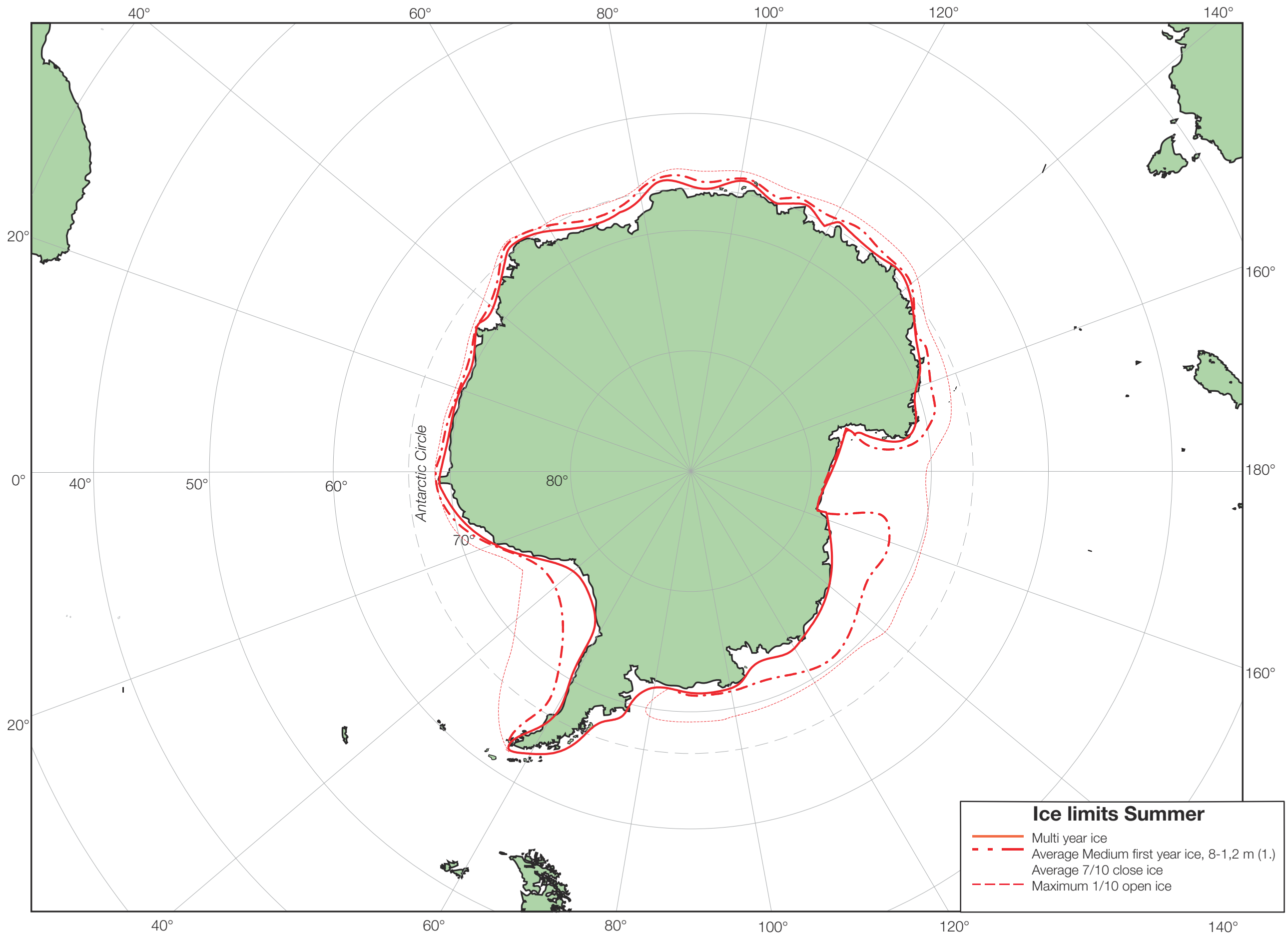


Figure 2.4.4 Ice limits Antarctica Summer

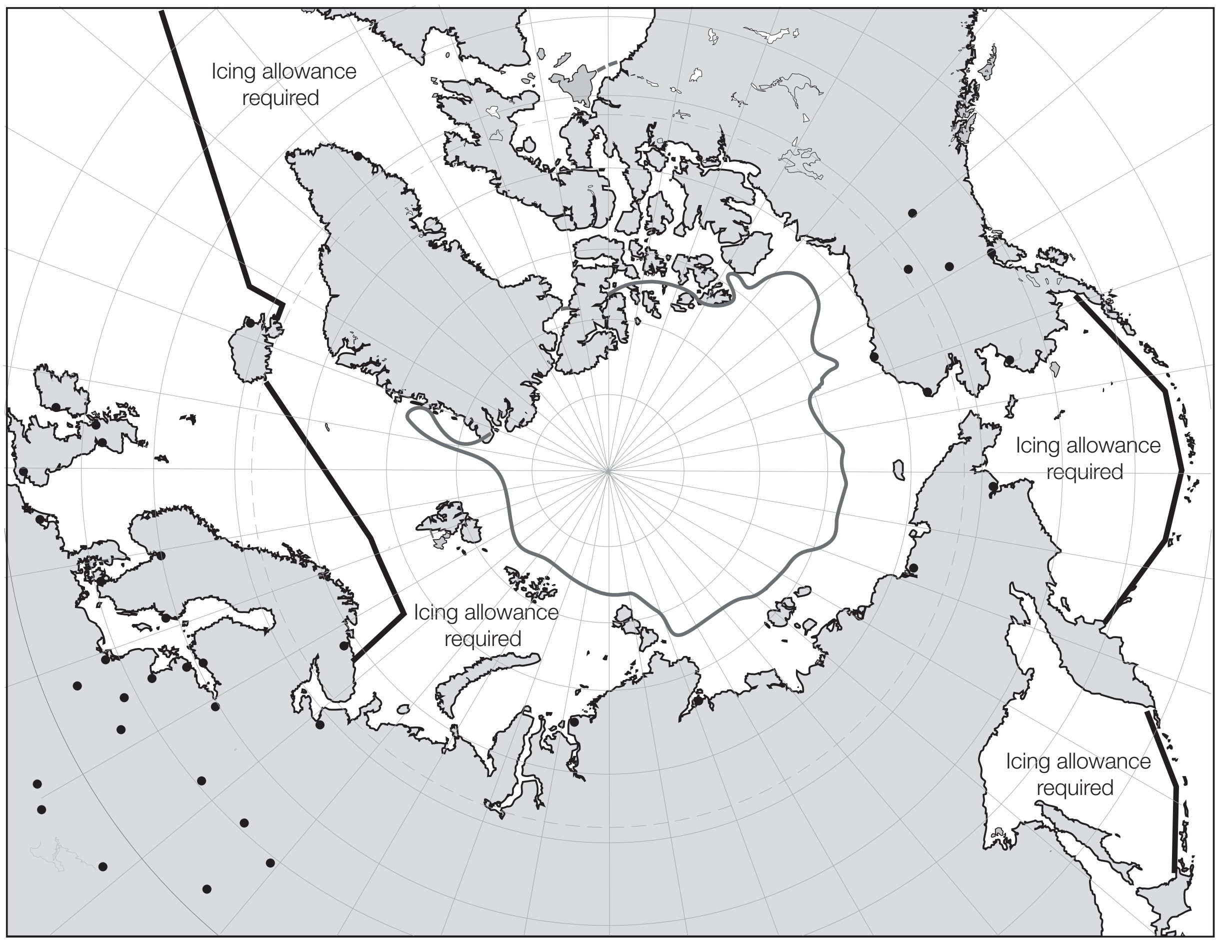


Figure 2.4.5 Ice accretion limits Arctic

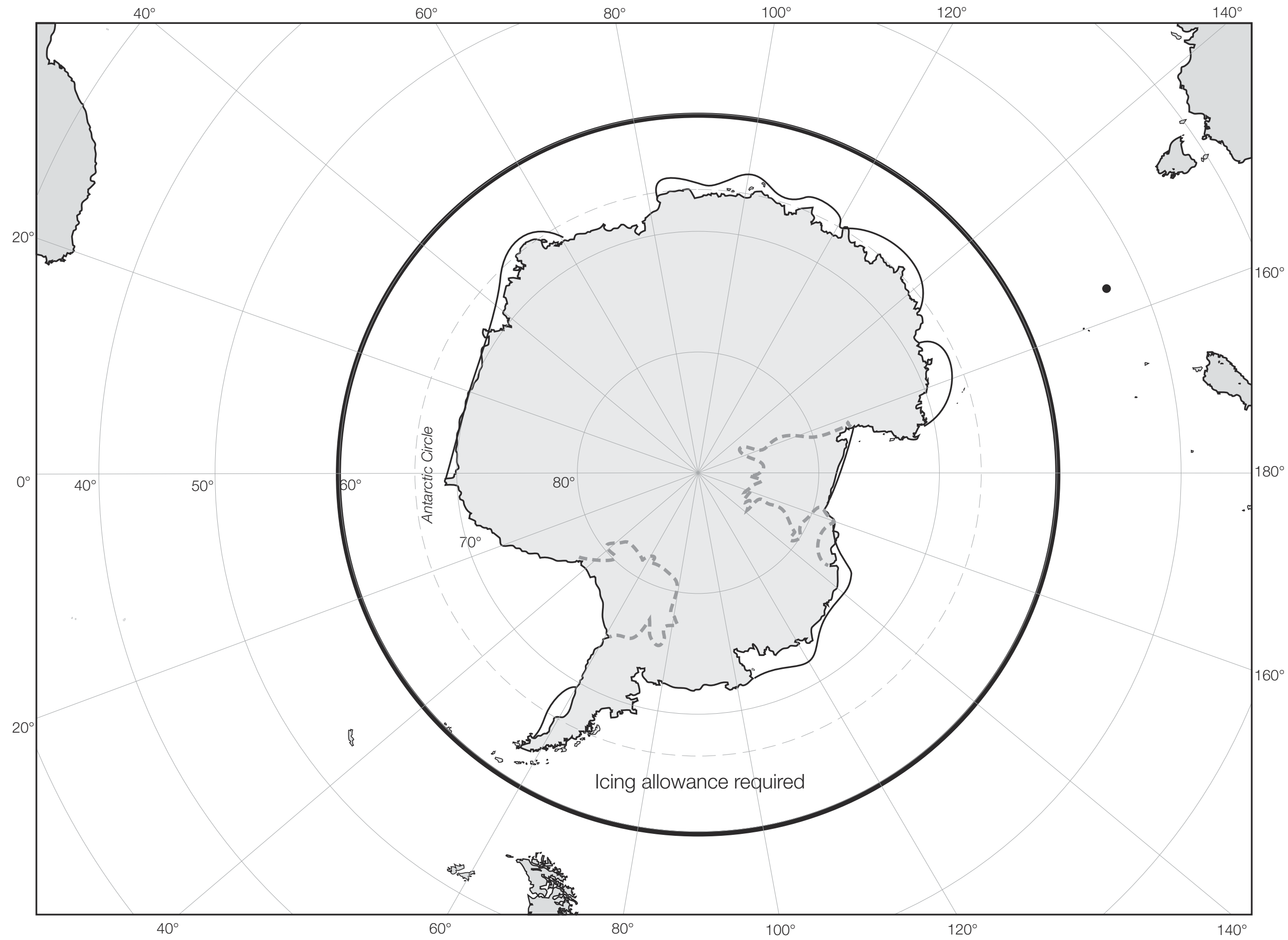


Figure 2.4.6 Ice accretion limits Antarctica

Section

■ Section 1 Introduction

1.1 General

1.1.1 This Chapter contains information regarding the derivation of local design loads that are to be used for the assessment of scantlings to local loads as specified in *Vol 1, Pt 6, Ch 2 Design Tools*

1.1.2 The formulae for ship motion loads given in this Chapter are suitable for all ships that operate in the displacement mode. Ship motion loads for ships that operate in the fully planing mode will need to be specially considered.

1.1.3 *Figure 3.1.1 Overview of derivation of local design loads* gives an overview of the contents of this Chapter, the locations of the local load components and the route through the Chapter.

1.2 Environmental conditions

1.2.1 The environmental conditions for the determination of the local loads are to be based on the normal environmental design criteria specified in *Vol 1, Pt 5, Ch 2, 2.3 Wave environment* unless otherwise stated.

1.2.2 The wave height factor for local loads, f_{Hs}, is dependent on the service area notation and is to be taken as follows:

f_{Hs} = 1,0 for SA1 service area notation, i.e. unrestricted sea-going service

otherwise

$$f_{Hs} = \frac{design\ wave\ height\ for\ the\ restricted\ service}{design\ wave\ height\ for\ unrestricted\ service}$$

$$= \frac{H_{\mathrm{dw}}}{H_{\mathrm{dw}}\ for\ SA1}$$

f_{Hs} is not to be taken as less than 0,5

H_{dw} is given in *Vol 1, Pt 5, Ch 2, 2.3 Wave environment 2.3.3*.

1.2.3 All other environmental parameters are defined in *Vol 1, Pt 5, Ch 2 Environmental Conditions*.

1.2.4 The local design loads for assessment of the residual strength notation, **RSA**, or for special loading conditions where the ship will not experience severe weather or severe sea states may be adjusted for the appropriate environmental conditions. A reduced wave height factor, f_{Hs}, may be applied, *see Vol 1, Pt 5, Ch 3, 5.10 Design loads for RSA notation assessment*and *Vol 1, Pt 5, Ch 3, 5.10 Design loads for RSA notation assessment 5.10.3*.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate sub-Section. L_{WL}, B, B_{WL}, D, T and C_b are defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*

f_{Hs} = wave height factor for service area, *see Vol 1, Pt 5, Ch 3, 1.2 Environmental conditions 1.2.2*

V_{cr} = two thirds the cruising speed, in knots

V_{sp} = is to be taken as the greater of the cruising speed or two thirds the sprint speed, in knots. For ships where it is not required to maintain high speeds in severe weather then the value of V_{sp} may be specially considered

T = mean draught at midships to the design waterline, based on L_{WL}, measured from the baseline

T_x = local draught to design waterline at longitudinal position under consideration measured above the baseline is to be taken as the horizontal plane passing though the bottom of the moulded hull at midships, *see Figure 3.1.2 Definition of symbols*

x_{wl} = longitudinal distance, in metres, measured forwards from the aft end of the L_{WL} to the position or centre of gravity of the item being considered

y = transverse distance, in metres, from the centreline to the centre of gravity of the item being considered. y is positive to port and negative to starboard

z = vertical distance, in metres, from the base line to the position or centre of gravity of the item being considered. z is positive above the baseline

Normally the following definitions are to be applied:

For a longitudinally framed plate panel, z is to be taken at the panel centre

For a transversely framed plate panel, z is to be taken at two thirds of the panel height

For short stiffener members: z is to be taken at the stiffener mid position

For long stiffener members: z is generally to be taken at the stiffener mid position, but may need to be specially considered, especially when there is a significant pressure variation along its length

z_k = vertical distance of the underside of the keel above the baseline, in metres, *see Figure 3.1.2 Definition of symbols*

Δ = moulded displacement of the ship, in tonnes

1.3.2 **Froude Number F_n.** The Froude number is a nondimensional parameter which is the primary constituent part of the wave making resistance and which dictates the maximum displacement speed. It is defined as:

$$F_n = \frac{V_m}{\sqrt{g\,L_{WL}}}$$

where

g = is the acceleration due to gravity and is taken to be 9,81 m/s^2

L_{WL} = is defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions 1.3.1*

V_m = is the appropriate ship speed in m/s.

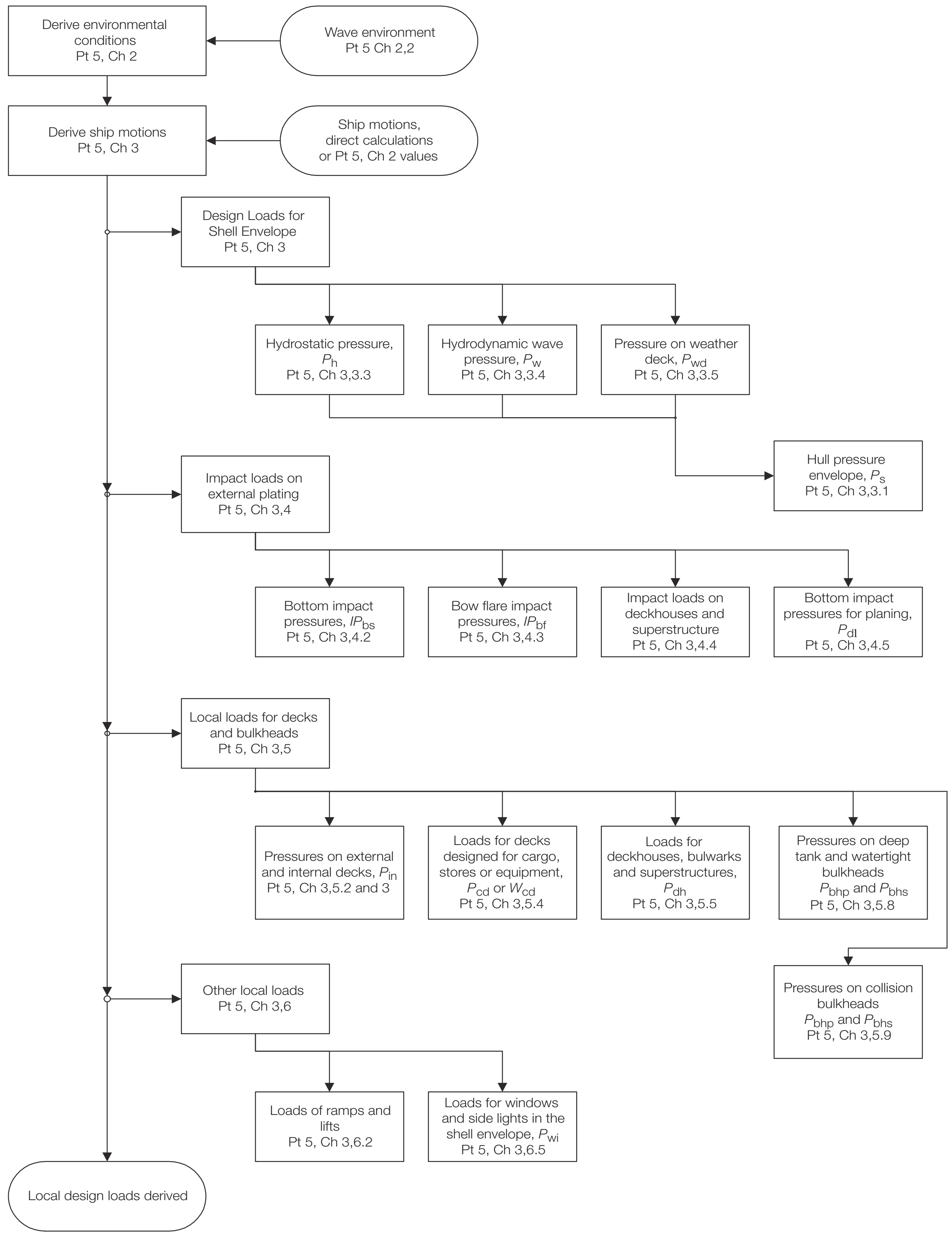
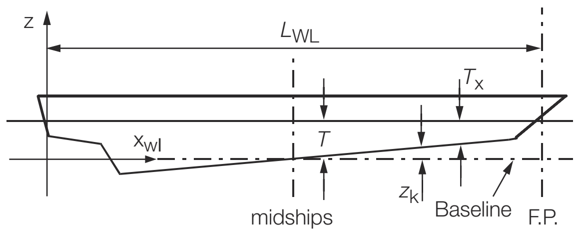


Figure 3.1.1 Overview of derivation of local design loads



NOTE
For any position $T = z_k + T_x$

Figure 3.1.2 Definition of symbols

1.3.3 **Design loading condition.** The design loading condition is to be taken as the normal operating deep draft condition with tanks and consumables, etc in the departure state. Where there is a significant variation in loading conditions or operating modes, then it may be necessary to consider additional loading conditions which represent the extremes of service requirements. For example:

- a ship which can operate in displacement and non-displacement modes;
- a ship which is required to operate at a much deeper draft than the normal sea going draft for off-loading payload.
- a ship which is required to be involved in humanitarian emergency evacuation incidents or similar situations where short term overloading may be necessary.

1.3.4 **LCG.** The LCG is the longitudinal centre of gravity of the ship measured in metres from the aft end of the L_{WL} for the design loading condition.

1.3.5 **Displacement mode.** Displacement mode means the regime, whether at rest or in motion, where the weight of the ship is fully or predominantly supported by hydrostatic forces. Typically this applies to craft with a Taylor Quotient, Γ, less than 3. However, some craft are designed to plane with Γ less than 3 and these should be considered as operating in the non-displacement mode.

1.3.6 **Fully planing mode or Non-displacement mode.** Non-displacement mode means the normal operational regime of a ship when non-hydrostatic forces substantially or predominantly support the weight of the ship. Typically this applies to craft with a Taylor Quotient, Γ, greater than 3. However, some craft are designed not to plane with Γ greater than 3 and these should be considered as operating in the displacement mode unless they are classified as a high speed craft.

1.3.7 Taylor Quotient Γ. The Taylor Quotient is defined as:

$$\Gamma = \frac{V_m}{\sqrt{L_{WL}}}$$

where

V_m = is defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions 1.3.2*

L_{WL} = is defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions 1.3.1*.

1.3.8 **Support girth G_S**. The support girth is the girth distance at the LCG, in metres, and is to be calculated as follows:

- For craft with chines, it is to be taken as the distance around the shell plate between the girth chine locations, *see Figure 3.1.3 Definition of girth chine location, B_C, B_{WL} and G_S when chine is below deepest load waterline*. Girth chine location is to be taken as the lowest chine above which the shell plate has an angle to the horizontal greater than 50°.
- For craft where the design waterline intercepts the shell plate below the bilge tangential point or the girth chine location, the support girth is to be taken as the distance around the shell plate up to the design waterline, *see* Fig. *Figure 3.1.4 Definition of girth chine location, B_C, B_{WL} and G_S when chine is above deepest load waterline*.

- For craft with round bilges, it is to be taken as the distance around the shell plate between the bilge tangential points of the hull. The bilge tangential point is defined as the tangential point of the bilge with an oblique line sloped at 50° to the horizontal at the LCG, *see Figure 3.1.5 Definition of bilge tangential point, B_C, B_{WL} and G_S* .
- For multi-hull craft, it is to be taken as the summation of girths for each individual hull between the inner and outer bilge tangential points or chines, as appropriate.

The definition aims to define the canoe body. Narrow keels and skegs can be ignored.

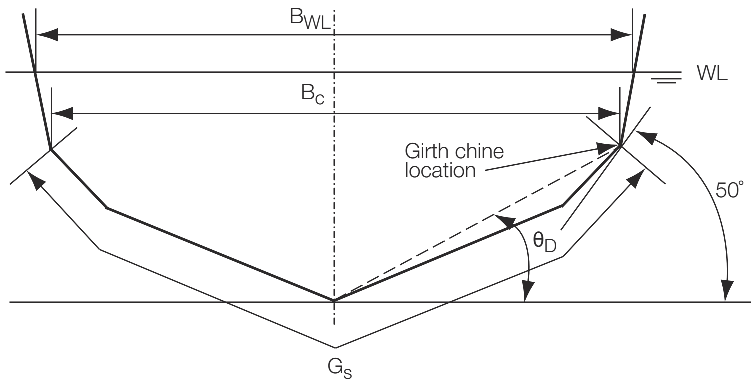


Figure 3.1.3 Definition of girth chine location, B_C, B_{WL} and G_S when chine is below deepest load waterline

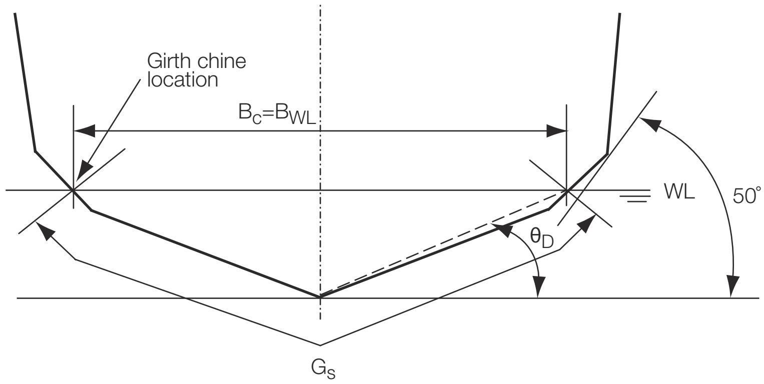


Figure 3.1.4 Definition of girth chine location, B_C, B_{WL} and G_S when chine is above deepest load waterline

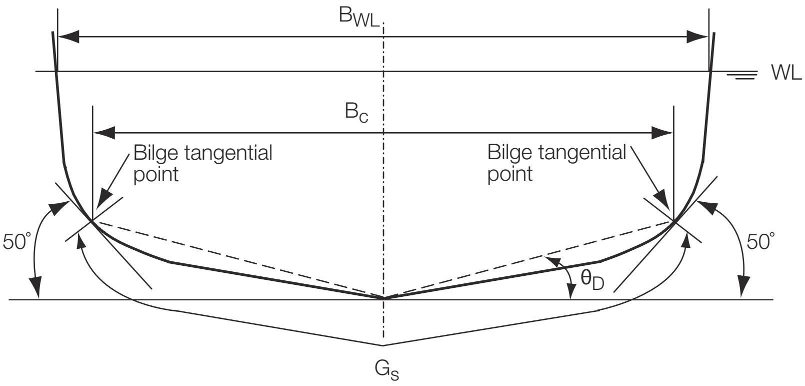


Figure 3.1.5 Definition of bilge tangential point, B_C, B_{WL} and G_S

Section 2
Motion response

2.1 General

2.1.1 The motions of the ship are to be considered in deriving the loads acting on the ship. The formulae given in this section may be utilised or ship motion design values may be derived by direct calculation methods or model testing.

2.2 Ship motions

2.2.1 The ship motion response data given in *Table 3.2.1 Ship motions* are to be used in the design calculations. Alternatively, the ship motion responses may be derived by direct calculation or equivalent methods.

2.3 Design accelerations

2.3.1 The non-dimensional ship motion acceleration values given in this Section are to be used in the design calculations. The equations given here are applicable to ships with conventional hull forms operating in the displacement mode at their normal ship service speed or cruising speed. It is not normally necessary to consider the ship motion or acceleration values at sprint speeds unless there is a particular requirement to operate at sprint speeds in severe seastates.

2.3.2 The following formulae are given as guidance for the components of acceleration due to ship motions and apply for ships with a length exceeding 50 m and where the speed is such that the ship is operating within the displacement mode based on normal ship service speed. Typically this will apply to most ships with displacement hull forms that are not designed to operate in the planing regime.

Vertical acceleration due to heave, pitch and roll motions

$$a_z = \pm\sqrt{\left(a_{heave}{}^2 + a_{pitch}{}^2 + a_{rollz}{}^2\right)}$$

Transverse acceleration due to sway, yaw and roll motions

$$a_y = \pm\sqrt{\left(a_{sway}{}^2 + a_{yaw}{}^2 + a_{rolly}{}^2\right)}$$

Longitudinal acceleration due to surge motions

$$a_x = \pm a_o\sqrt{\left(0,06 + \mathrm{A}^2 - 0,25\mathrm{A}\right)}$$

where

A = $f_{HS} f_{st}\left(0,7 - \frac{L_{WL}}{1200} + \frac{5(z - T)}{L_{WL}}\right)\left(\frac{0,6}{C_b}\right)$

and

a_x, a_y and a_z = are the maximum dimensionless accelerations (i.e. relative to the acceleration of gravity) in the respective directions and are considered as acting separately for calculation purposes

a_x = measured positive in the forward direction

a_y = measured positive in the transverse direction to port.

a_z = measured positive in the downwards direction, i.e. adds to g

Note

a_x = includes the component due to static weight in the longitudinal direction due to pitching

Note

a_y = includes the component due to static weight in the transverse direction due to rolling

Note

a_z = does not include the component due to static weight

Note a_o, a_{heave}, a_{pitch}, a_{rollz}, a_{sway}, a_{yaw}, a_{rolly} and A are defined in *Table 3.2.1 Ship motions*

Note

f_{st} = is defined in *Table 3.2.1 Ship motions*

Note

f_{Hs} = is defined in *Vol 1, Pt 5, Ch 3, 1.2 Environmental conditions 1.2.2*

Note T, L_{WL}, C_b and z are defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions 1.3.1*

2.4 Design vertical acceleration for ships in the planing regime

2.4.1 The design vertical acceleration for the derivation of bottom impact pressures for ships operating in the planing regime may be derived using the following Sections.

Table 3.2.1 Ship motions

Motion			Acceleration
Heave		a_{heave}	$= a_o$
Pitch		a_{pitch}	$= a_o\left(5,3 - \frac{45}{L_{WL}}\right)\left(\frac{x_{wl} - L_{CG}}{L_{WL}}\right)\left(\frac{0,6}{C_b}\right)0,75$
Sway Yaw		a_{sway} a_{yaw}	$= a_o 0,78$ $= a_o\, 1,6\left(\frac{x_{wl} - L_{CG}}{L_{WL}}\right)$
Roll	Acceleration due to Roll Vertical direction	a_{rollz}	$= a_o\frac{0,6yK^{1,5}}{B_{WL}}$
Roll	Acceleration due to Roll Transverse direction	a_{rolly}	$= a_o\sqrt{K}\left(1 + 0,6K\left(\frac{z - T}{B_{WL}}\right)\right)$

		a_o	$= f_{Hs} f_{st} \left(\dfrac{0,2V}{\sqrt{L_{WL}}} + \dfrac{34 - \left(\dfrac{600}{L_{WL}}\right)}{L_{WL}} \right)$
Relative vertical motion		H_{rm}	$= C_{w,\min} \left(1 + \dfrac{k_r}{(C_b + 0,2)} \left(\dfrac{x_{wl}}{L_{WL}} - x_m \right)^2 \right)$

Symbols

f_{st} = correction factor for long term (10^{-8}) acceleration value to average of the highest 1/100 acceleration values

= 0,8

C_w = a wave head, in metres

= $f_{Hs} 0,0771 L_{WL} (C_b + 0,2)^{0,3} e^{(-0,0044 L_{WL})}$

$C_{w,min}$ = $\dfrac{C_w}{k_m} \sqrt{\dfrac{2,25}{k_r}}$

k_m = $1 + \dfrac{k_r (0,5 - x_m)^2}{(C_b + 0,2)}$

x_m = 0,45 – 0,6F_n but x_m is not to be less than 0,2

k_r = 2,25 for the determination of pressure loads in *Vol 1, Pt 5, Ch 3, 3 Loads on shell envelope*

k_r = 4,5 for the determination of impact loads in *Vol 1, Pt 5, Ch 3, 4 Impact loads on external plating*

V is appropriate design speed as follows:

V = V_{cr} for determination of pressure in *Vol 1, Pt 5, Ch 3, 3 Loads on shell envelope*, local design loads in *Vol 1, Pt 5, Ch 3, 5 Local design loads for decks and bulkheads* and *Vol 1, Pt 5, Ch 3, 6 Other local loads*, and all other loads unless specifically noted

= V_{sp} for determination of impact loads in *Vol 1, Pt 5, Ch 3, 4 Impact loads on external plating*

F_n = $\dfrac{0,515V}{\sqrt{g L_{WL}}}$

K = 1 in general. For particular loading conditions and hull forms, determination of K according to the formula below may be necessary

K = 13 GM / B_{WL}, but ≥ 1,0

GM = metacentric height, in metres

f_{HS} and B_{WL} are defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions 1.3.1*

L_{CG} is defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions 1.3.4*

Note 1. Heave motion is measured positive upwards.

Note 2. Pitch motion is measured positive bow downwards.

Note 3. Sway motion is measured positive to port.

Note 4. Yaw motion is measured positive bow to port.

Note 5. Roll motion is measured positive port side upwards.

2.4.2 The non-dimensional vertical acceleration at the LCG, a_{op}, is defined as the average of the 1/100 highest accelerations and is to be taken as:

$$a_{op} = 5,66 g\, \theta_B\, L_1 (H_1 + 0,084)(5 - 0,1\theta_D) F_n^{\,2}\, 10^{-3}$$

where

F_n = Froude number based on V_{sp}, where V_{sp} is defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions 1.3.1*, F_n is defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions 1.3.2*

g = acceleration due to gravity (9,81 m/sec^2)

L_1 = $\dfrac{L_{WL} B_c^{\,3}}{B_{WL} \Delta}$, but $\dfrac{L_{WL}}{B_{WL}}$ is not to be taken as less than 3

where

H_1 = $\frac{H_{dw}}{B_{WL}}$ but not less than 0,2

B_c = breadth of hull between the chines or bilge tangential points at the LCG, as appropriate, in metres

H_{dw} = design wave height in metres, *see Vol 1, Pt 5, Ch 2, 2.3 Wave environment 2.3.3*

θ_D = deadrise angle at the LCG, in degrees, but is not to be taken as greater than 30°, *see* Notes 1 and 2 and *Figure 3.1.5 Definition of bilge tangential point, B_C, B_{WL} and G_S*

θ_B = running trim angle in degrees, but is not to be taken as less than 3°.

Δ is defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions 1.3.1*

LCG is defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions 1.3.4*

B_{WL} and L_{WL} are defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*

Note 1. For ships with no clearly defined deadrise angle at the LCG, the angle, in degrees, to the horizontal line at the LCG formed by joining the lowest point of the hull or underside of keel and the bilge tangential point is to be taken as the deadrise angle θ_D, *see Figure 3.1.5 Definition of bilge tangential point, B_C, B_{WL} and G_S*

Note 2. For ships with hulls of asymmetric section, where the inner and outer deadrise angles differ, the smaller of the two angles is to be used.

2.4.3 Where the Froude number, F_n, is greater than 1,8, the motion response criteria are to be specially considered.

2.4.4 The vertical non dimensional acceleration, a_z, at any given distance x along the hull may be taken as:

$$a_z = a_{op}\left(1,0 - 0,32\frac{\left(X_{wl} - L_{CG}\right)}{L_{WL}} + 1,76\left(\frac{X_{wl} - L_{CG}{}^2}{L_{WL}{}^2}\right)\right)$$

where

a_z = is the vertical acceleration in terms of g

x_{wl} = distance from aft end of L_{WL}, in metres, to the point at which the vertical acceleration is calculated

LCG is defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions 1.3.4*

■ *Section 3*
Loads on shell envelope

3.1 Pressures on the shell envelope

3.1.1 The design pressures for the shell envelope including exposed decks are to include the effects of combined static and dynamic load components. In addition the effects of impact or slamming loads are also to be considered, but these may be treated separately, *see Vol 1, Pt 5, Ch 3, 4 Impact loads on external plating*

3.1.2 The individual pressure components are given in *Vol 1, Pt 5, Ch 3, 3.3 Hydrostatic pressure on the shell plating, Ph* and the combined pressure to be applied to the shell envelope is given in *Vol 1, Pt 5, Ch 3, 3.2 Combined hydrostatic and hydrodynamic pressure on the shell plating, Ps*. The pressure to be applied to exposed and weather decks is given in *Vol 1, Pt 5, Ch 3, 3.5 Pressure on exposed and weather decks, Pwd*.

3.2 Combined hydrostatic and hydrodynamic pressure on the shell plating, P_s

3.2.1 The total pressure distribution, P_s, in kN/m^2 acting on the shell plating envelope due to hydrostatic and hydrodynamic pressures is illustrated in *Figure 3.3.1 Combined pressure distributution, Ps* and is to be taken as specified in *Table 3.3.1 Shell envelope pressure, Ps*

3.3 Hydrostatic pressure on the shell plating, P_h

3.3.1 The pressure, P_h, acting on the shell plating up to the design waterline due to hydrostatic pressure is to be taken as:

$$P_h = 10 (T_x - (z - z_k)) \text{ kN/m}^2$$

where

= T_x, z and z_k are defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions*

3.4 Hydrodynamic wave pressure, P_w

3.4.1 The hydrodynamic wave pressure distribution, P_w, around the shell envelope up to the design waterline, i.e. $z \leq T_x + z_k$, is to be taken as the greater of the following:

P_m kN/m^2 (relative motion)

P_p kN/m^2 (pitching motion)

where

P_m and P_p are defined in *Vol 1, Pt 5, Ch 3, 3.4 Hydrodynamic wave pressure, Pw 3.4.2* and *Vol 1, Pt 5, Ch 3, 3.4 Hydrodynamic wave pressure, Pw 3.4.3*.

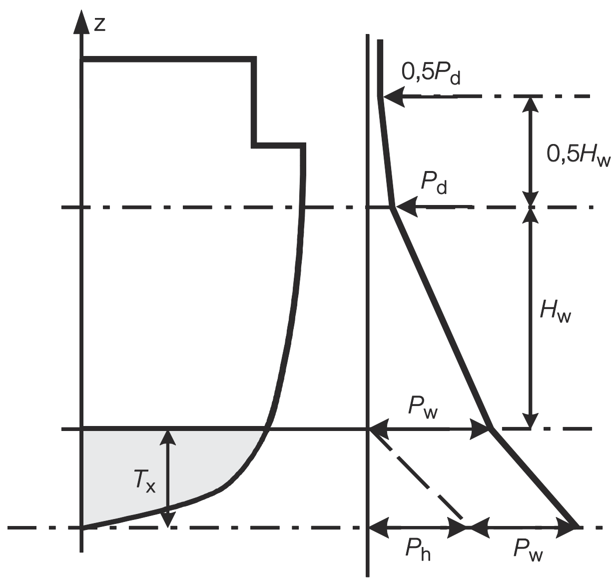


Figure 3.3.1 Combined pressure distribututíon, P_s

Table 3.3.1 Shell envelope pressure, P_s

Vertical location i.e. z value	Shell envelope pressure, P_s kN/m^2
for $z \leq T_x + z_k$ i.e. up to the design waterline	$P_h + P_w$
At $z = T_x + z_k + H_w$	P_d
At $z \geq T_x + z_k + 1{,}5H_w$	$0{,}5P_d$
Symbols	

P_h is the hydrostatic pressure, *see Vol 1, Pt 5, Ch 3, 3.3 Hydrostatic pressure on the shell plating, Ph*
P_w is the hydrodynamic wave pressure, *see Vol 1, Pt 5, Ch 3, 3.4 Hydrodynamic wave pressure, Pw*
P_d is the weather deck pressure, *see Vol 1, Pt 5, Ch 3, 3.5 Pressure on exposed and weather decks, Pwd 3.5.2*
H_w is the nominal wave limit height, *see Vol 1, Pt 5, Ch 3, 3.4 Hydrodynamic wave pressure, Pw 3.4.4*
P_h and P_w are to be derived at the appropriate vertical position, z
T_x, z and z_k are defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions*
Note Pressure values at other z values are to be derived by interpolation.

3.4.2 The distribution of hydrodynamic pressure up to the design waterline, P_m, due to relative motion is to be taken as:

$$P_m = 10\, f_z\, H_{rm} \text{ kN/m}^2$$

where

f_z = the vertical distribution factor

$$= K_z + (1 - K_z)\left(\frac{Z - Z_K}{T_x}\right)$$

$k_z = e^{-u}$

$$u = \left(\frac{2\,\pi\, T_x}{L_{WL}}\right)$$

H_{rm} is defined in *Table 3.2.1 Ship motions z,z*$_k$, T_x and L_{WL} are defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions*.

3.4.3 The distribution of hydrodynamic pressure up to the design waterline due to pitching motion, P_p, is to be taken as:

$$P_p = 10\, H_{pm} \text{ kN/m}^2$$

where

$$H_{pm} = 1,1 f_{HS}\left(\frac{2X_{Wl}}{L_{WL}} - 1\right)\sqrt{L_p} \text{ but not less than } 0,3 f_{HS}\sqrt{L_{wL}}$$

where

$L_P = L_{WL}$ but ≤ 150 m

x_{wl}, L_{WL} and f_{Hs} are defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions*.

3.4.4 The nominal wave limit height, H_w, above the design draft, T_x, is to be taken as:

$$H_w = 2\, H_{rm} \text{ m}$$

where
H_{rm} is given in *Table 3.2.1 Ship motions*

3.5 Pressure on exposed and weather decks, P_{wd}

3.5.1 The pressure acting on weather decks, exposed decks or decks designed for prolonged immersion, P_{wd}, is illustrated in *Figure 3.3.2 Weather deck pressure distribution, P_{wd}* and is to be taken as specified in *Table 3.3.2 Exposed/weather deck pressure, P_{wd}*

3.5.2 The minimum design pressure for weather decks, P_d, above the 0,5H_w limit line and below the 1,0H_w limit line is to be taken as:

$P_d = 6 + 6f_L f_{Hs}$ kN/m^2

where

f_L = a location factor

$$1 + 4\left(\frac{X_{wl}}{L_{WL}} - 0,75\right)$$

but not less than 1,0

L_{WL} and x_{wl} are defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions* f_{Hs} is defined in *Vol 1, Pt 5, Ch 3, 1.2 Environmental conditions*.

3.5.3 If a bulwark is fitted at the deck edge then consideration will be given to allowing the height of the top of the bulwark to be used for the pressure calculation.

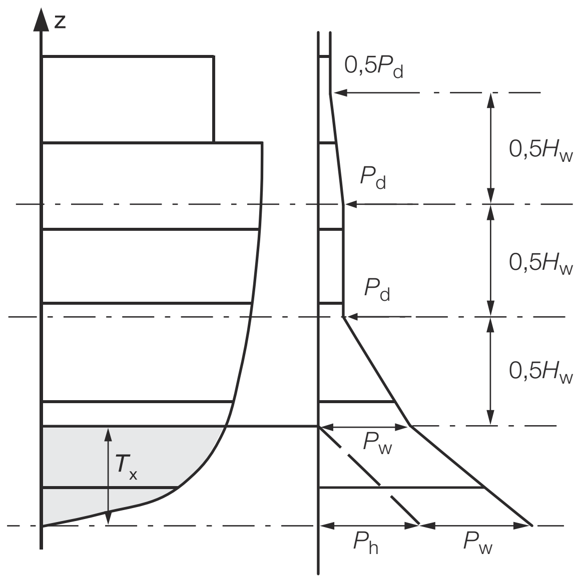


Figure 3.3.2 Weather deck pressure distribution, P_{wd}

Table 3.3.2 Exposed/weather deck pressure, P_{wd}

Vertical location i.e. z value	Exposed/weather deck pressure, P_{wd} kN/m^2
for $z \le T_x + z_k$ i.e. up to the design waterline	$P_h + P_w$
At $z = T_x + z_k + 0,5H_w$	P_d
At $z = T_x + z_k + 1,0H_w$	P_d
At $z \ge T_x + z_k + 1,5H_w$	0,5P_d
Symbols	

P_h is the hydrostatic pressure, *see Vol 1, Pt 5, Ch 3, 3.3 Hydrostatic pressure on the shell plating, Ph*
P_w is the hydrodynamic wave pressure, *see Vol 1, Pt 5, Ch 3, 3.4 Hydrodynamic wave pressure, Pw*
P_d is the weather deck pressure, *see Vol 1, Pt 5, Ch 3, 3.5 Pressure on exposed and weather decks, Pwd 3.5.2*
H_w is the nominal wave limit height, *see Vol 1, Pt 5, Ch 3, 3.4 Hydrodynamic wave pressure, Pw 3.4.4*
P_h and P_w are all taken at the appropriate vertical position, z
T_x, z and z_k are defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions*
NOTE Pressure values at other z values are to be derived by interpolation.

■ *Section 4*
Impact loads on external plating

4.1 General

4.1.1 The effects of impact or slamming loads on the shell envelope are to be considered. This section gives formulations for equivalent design pressure loads. Alternatively the impact pressure loads may be derived using suitable direct calculation methods.

4.1.2 The methods below produce average instantaneous impact pressures which need to be converted to equivalent static pressures by application of a dynamic load factor, *see Vol 1, Pt 6, Ch 2, 5 Dynamic loading* and *Vol 1, Pt 6, Ch 3, 14 Strengthening for bottom slamming* and *Vol 1, Pt 6, Ch 3, 15 Strengthening for wave impact loads above waterline*.

4.1.3 These methods are based on the Ochi-Motter slamming approach and are equivalent to the standard direct calculation procedure. The values of m_0, variance of the relative vertical motion, and m_1, variance of the relative vertical velocity, may be derived using direct calculations. In this case the variances are to be based on sea states as defined by the normal design assessment environmental criteria, *see Vol 1, Pt 5, Ch 2, 2.3 Wave environment*.

4.2 Bottom impact pressure, IP_{bi}

4.2.1 The bottom impact pressure due to slamming, IP_{bi}, is to be derived using the method given below. This method will produce impact pressures over the whole of the underwater plating region:

$$IP_{bi} = 0{,}5 k_{sl} V_{bs}^{\ 2} \text{ kN/m}^2$$

where

K_{sl} = hull form shape coefficient

= $\dfrac{\pi}{tan\ \beta_p}$ for $\beta_p \geq 10$

= $28\,(1 - \tan(2\beta_p))$ for $\beta_p < 10$

β_p = deadrise angle,in degrees, *see Figure 3.4.1 Bow flare and bottom slamming angles*

V_{bs} = slamming velocity, in m/s, and is given by

= $\sqrt{V_{th}^{\ 2} + 2 m_1 \ln(N_{sl})}$ for $N_{sl} \geq 1$

= 0 for $N_{sl} < 1$

V_{th} = threshold velocity for slamming, in m/s, to be taken as:

= $\sqrt{10}$

N_{sl} = No. of slams in a 3 hour period and is given by

where

$= 1720 PR_{Sl} \sqrt{\frac{m_1}{m_0}}$

PR_{sl} = probability of a slam and is given by

$= e^{-u}$

$u = \left(\frac{Z_{Wl}^{2}}{2m_o} + \frac{V_{th}^{2}}{2m_1} \right)$

Z_{wl} = distance of the centroid of the area of plating or stiffener to the local design waterline

$= z - (T_x + z_k)$

m_1 = variance of the relative vertical velocity

$= 0,25\,(\omega_e f_{sl} H_{rm})^2$

m_0 = variance of the relative vertical motion

$= 0,25\,(f_{sl} H_{rm})^2$

ω = effective wave frequency based on 80 per cent ship length

$= \sqrt{\frac{2\pi g}{0,8 L_{WL}}}$

ω_e = effective encounter wave frequency

$= \omega \left(1 + \frac{0,2\,\omega V_{sp}}{g} \right)$

H_{rm} = relative vertical motion based on V_{sp}, *see Table 3.2.1 Ship motions*

f_{sl} = probability level correction factor for relative vertical motion

= 1,0

V_{sp}, z, z_k and T_x are defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions*

See Figure 3.4.1 Bow flare and bottom slamming angles.

4.2.2 For the purposes of deriving the dynamic load factor, the rise time of the impact pressure may be taken as:

$$t_r = \frac{1}{4\sqrt{IP_{bi}}} \text{ seconds}$$

It is assumed that the impact pressure may be represented by a triangular pulse load.

4.3 Bow flare and wave impact pressures, IP_{bf}

4.3.1 This Section is applicable to:

(a) Bow flare region.
(b) Sides and undersides of sponsons.
(c) Other parts of the side shell plating close to and above the design waterline that are expected to be subjected to wave impact pressures.

The bow flare wave impact pressure, wave impact pressure on sponsons and other parts of the side shell plating above the design waterline, IP_{bf}, in kN/m^2, due to relative motion is to be taken as:

$$IP_{bf} = 0,5\,(k_{bf} V_{bf}^{\,2} + k_{rv} H_{rv} V_{rv}^{\,2}) \text{ kN/m}^2$$

where

k_{bf} = hull form shape coefficient for wave impacts

= $\dfrac{\pi}{\tan\,\psi}$ for ψ ≥ 10

= 28 (1 – tan(2 ψ)) for ψ < 10

V_{bf} = wave impact velocity, in m/s, and is given by

= $\sqrt{V_{\mathrm{thbf}}{}^{2} + 2\mathrm{m}_1 \mathrm{In}\left(\mathrm{N_{bf}}\right)}$ for $N_{bf} \geq 1$

= 0 for $N_{bf} < 1$

V_{thbf} = threshold velocity for wave impact, in m/s, to be taken as:

= $\dfrac{\sqrt{10}}{cos\ \alpha_p}$

N_{bf} = No of wave impacts in a 3 hour period and is given by

= $1720 PR_{\mathrm{bf}}\sqrt{\dfrac{m_1}{m_0}}$

PR_{bf} = probability of a wave impact and is given by e^{-u}

u = $\left(\dfrac{Z_{WL}{}^{2}}{2m_0} + \dfrac{V_{thbf}{}^{2}}{2m_1}\right)$

k_{rv} = hull form shape coefficient for impact due to forward speed

= $\dfrac{\pi}{tan\left(90 - \alpha_p\right)}$ for $\alpha_p \leq 80$

= 28 (1 – tan(2 (90 – α_p))) for $\alpha_p > 80$

H_{rv} = relative wave heading coefficient

= 1,0 for $\gamma_p \geq 45$

= cos(45-γ_p) for γ_p < 45 and ≥ 0

= 0 for $\gamma_p < 0$

V_{rv} = relative forward speed, in m/s

= 0,515 V_{sp} sin(γ_p)

α_p = buttock angle measured in the longitudinal plane, in degrees, *see Figure 3.4.1 Bow flare and bottom slamming angles*

ψ = effective deadrise angle in degrees.

For C_b > 0,6, ψ is to be taken as the maximum of α_p and β_p, *see Figure 3.4.1 Bow flare and bottom slamming angles*

For C_b ≤ 0,6, ψ is to be taken as the maximum of α_p and β

where

β = β_p – 10°, but is to be taken as not less than 0°

NOTE

The 10° deduction is to allow for the effects of roll motion on the impact pressures.

γ_p = waterline angle, measured in the horizontal plane, in degrees, *see Figure 3.4.1 Bow flare and bottom slamming angles*

C_b = Block coefficient as defined in *Vol 1, Pt 3, Ch 1, 5 Definitions*

= z_{wl}, m_1, m_0, are defined in 4.2 but are to be calculated using:

f_{sl} = probability level correction factor for relative vertical motion

= 1,0 for ships $C_b \leq 0,6$

= 1,2 for ships $C_b > 0,6$

Note Where only two angles are known and are measured in the orthogonal planes, then the third angle may be obtained by the following expression:

α_p = $\tan^{-1}(\tan\beta_p \tan_\gamma)$

If the area of plating under consideration has a waterline angle which is re-entrant or decreasing, e.g. in the stern region, then the relative wave heading coefficient, H_{rv}, and the speed V_{sp}, used in the derivation of H_{rm}, are to be taken as zero. V_{sp} is defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions 1.3.1*

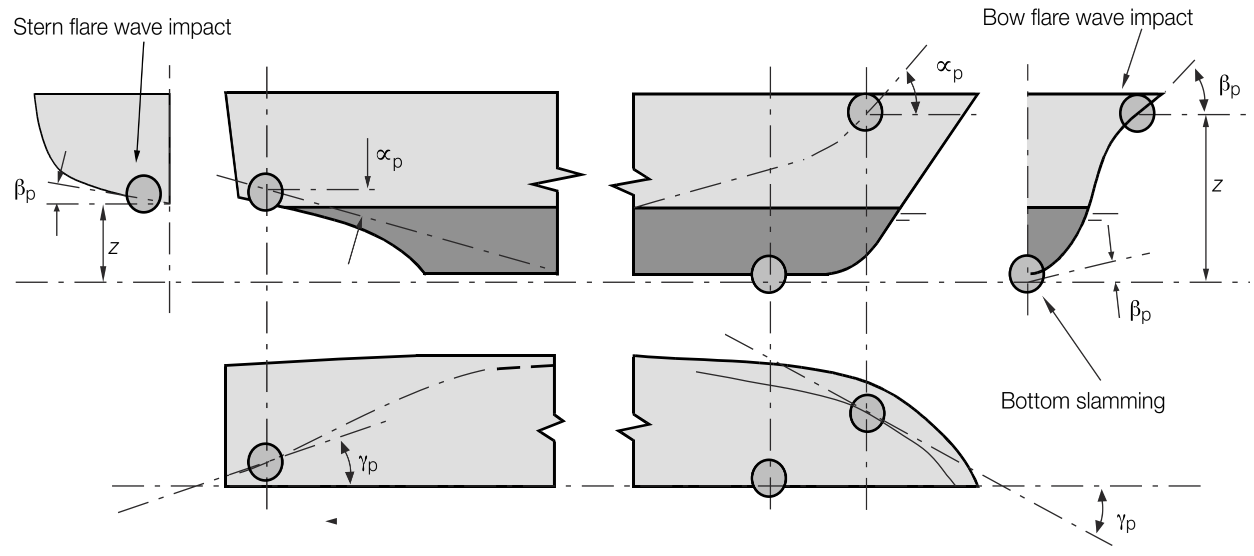


Figure 3.4.1 Bow flare and bottom slamming angles

4.3.2 For the purposes of deriving the dynamic load factor, the rise time of the wave impact pressure may be taken as:

$$t_r = \frac{1}{4\sqrt{IP_{bf}}} \text{ seconds}$$

It is assumed that the wave impact pressure may be represented by a triangular pulse load.

4.3.3 The extents around the girth of the bow flare wave impact pressure are to be derived as follows:

(a) the vertical slam extent, g_{bfv}, is to be taken as:

$$g_{bfv} = \frac{4}{\sin\psi\sqrt{8K_{bf}}}\ m$$

(b) the horizontal slam extent, g_{bfh}, is to be taken as:

g_{bfh} = 4 m

where

k_{bf} and ψ are given in *Vol 1, Pt 5, Ch 3, 4.3 Bow flare and wave impact pressures, IPbf 4.3.1*.

4.4 Impact loads on deckhouses and superstructures

4.4.1 Normally, it may be assumed that the equivalent static pressure loads given in *Vol 1, Pt 5, Ch 3, 5.5 Loads for deckhouses, bulwarks and superstructures, Pdh* make due allowance for impact loads on deckhouse fronts and sides.

4.5 Bottom impact pressure for ships operating in the planing regime

4.5.1 The equivalent static bottom impact pressure due to slamming, P_{dl} , at the LCG for planing hull forms is given by the following expression:

$$P_{\mathrm{dl}} = \frac{k_{\mathrm{dl}}\,\Delta\, f_{\mathrm{d\,l}}\left(1 + \mathrm{a}_{\mathrm{op}}\right)}{L_{\mathrm{WL}} G_{\mathrm{S}}}\ \mathrm{kN/m^2}$$

where

G_S = support girth in metres, as defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions 1.3.8*

L_{WL} = waterline length, in metres, *see Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions 1.3.1*

a_{op} = vertical acceleration as defined in *Vol 1, Pt 5, Ch 3, 2.4 Design vertical acceleration for ships in the planing regime*

k_d = hull form pressure factor

= 54

= For craft in continuous contact with water:

f_{dl} = 0,5 for x = 0,0 L_{WL}

= 1,0 for x = 0,5 L_{WL}

= 1,0 for x = 0,75 L_{WL}

= 0,5 for x = 1,0 L_{WL}

Intermediate values to be determined by linear interpolation.

Otherwise f_{dl} = 1,0.

■ Section 5
Local design loads for decks and bulkheads

5.1 General

5.1.1 This section gives formulations for design pressure loads for decks, watertight and deep tank boundaries including decks and bulkheads.

5.1.2 The loads acting on the deck structures are to reflect the intended purpose for each deck. If it is envisaged that the role of the ship will be such that it may be used for emergency evacuation incidents or similar situations, then the appropriate design loads are to be considered in the assessment. The maximum permissible deck loading are to be recorded in the Operations Manual or Stability Information Book.

5.1.3 Bulkheads and decks forming the boundary of tanks are to be assessed in accordance with the requirements for deep tanks using the loads defined in *Vol 1, Pt 5, Ch 3, 5.8 Design pressures for watertight and deep tank bulkheads and boundaries* and *Vol 1, Pt 5, Ch 3, 5.9 Design pressures for collision bulkheads* or the maximum load experienced in service, e.g. from RAS operations, whichever is the greater. For an open system the pressure height may be taken from the keel to the filling point open to the atmosphere.

5.2 Pressure on external decks

5.2.1 The standard pressure requirements for external decks are given in *Vol 1, Pt 5, Ch 3, 3.5 Pressure on exposed and weather decks, Pwd*. If the deck is also to be used for cargo, heavy equipment or similar, then the loads specified in *Vol 1, Pt 5, Ch 3, 5.4 Loads for decks designed for cargo or heavy equipment loads, Pcd and Wcd* are also to be applied. Consideration will be given to a reduction in the weather deck pressure loading if it can be shown that the cargo or equipment stowage makes the weather deck pressure requirements conservative.

5.3 Pressure on internal decks, P_{in}

5.3.1 The pressure acting on internal decks, P_{in}, not subject to cargo or heavy equipment loads is to be taken as:

P_{in} = 5 kN/m^2 for accommodation spaces

P_{in} = 7,5 kN/m^2 for main evacuation routes

P_{in} = 10 kN/m^2 for workshop spaces

P_{in} = 20 kN/m^2 for store spaces.

5.3.2 Alternatively the design pressure is to be based on the static loading on the deck with due allowance for inertial effects as follows:

$$P_{in} = W_{in} (1 + a_z) \text{ kN/m}^2$$

where the following values of static pressure are to be assumed

W_{in} = 3 kN/m^2 for accommodation spaces

W_{in} = 6 kN/m^2 for workshop spaces

W_{in} = 12 kN/m^2 for store spaces

a_z is defined in *Vol 1, Pt 5, Ch 3, 2.3 Design accelerations 2.3.2*.

5.3.3 The hydrostatic design pressure for decks specified as watertight shall be taken as that determined by the damage stability analysis and limit of watertight integrity.

5.3.4 The static design pressure for internal decks not specified as watertight may be provided by the designer.

5.4 Loads for decks designed for cargo or heavy equipment loads, P_{cd} and W_{cd}

5.4.1 Where the load applied to the deck can be considered as uniformly distributed, the cargo deck design pressure, P_{cd}, is to be taken as:

$$P_{cd} = W_{cd} (1 + a_z) \text{ kN/m}^2$$

where

a_z = is the non dimensional vertical acceleration given in *Vol 1, Pt 5, Ch 3, 2.3 Design accelerations 2.3.2*

W_{cd} = is the static pressure exerted by the cargo on the deck as specified by the designer in kN/m^2.

5.4.2 Where the load applied to the deck is not uniformly distributed, the likely actual forces and force distribution over the deck must be considered. The forces are to include the following if appropriate:

- gravity
- inertial forces due to ship motion.
- wind loads
- forces imposed by the securing arrangements
- wave impact loads
- icing loads

$$F_{cd} = W_{ma} (1 + a_z) \text{ kN}$$

where

W_{ma} is the weight of each mass item on the deck as specified by the designer in kN

5.5 Loads for deckhouses, bulwarks and superstructures, P_{dh}

5.5.1 The design normal pressure, P_{dh}, for the side, front and back panels of plating and stiffeners for deckhouses, bulwarks and superstructures is given by:

$$P_{dh} = C_1 P_s \text{ kN/m}^2$$

where

C_1 = $1{,}25C_2$ for exposed deckhouse fronts and superstructure fronts forward of $0{,}67L_R$

= $1{,}15C_2$ for exposed deckhouse fronts and superstructure fronts aft of $0{,}67L_R$

= 1,15 for exposed machinery casings

= 0,8 for the side and back panels of deckhouses that are stepped in from the deck edge by 1,0 m or more which are also above the nominal wave limit height, H_w, *see Vol 1, Pt 5, Ch 3, 3.4 Hydrodynamic wave pressure, Pw 3.4.4*

= 0,5 for non-exposed deckhouse and super structure fronts, sides and backs which are also above the nominal wave limit height

= 1,0 elsewhere

P_s = is to be taken at the height of the deck supporting the deckhouse front, side or back panel under consideration, P_s is defined in *Vol 1, Pt 5, Ch 3, 3.2 Combined hydrostatic and hydrodynamic pressure on the shell plating, Ps*

C_2 = 1,2 for panels below the nominal wave limit height

= 1,0 elsewhere

= Typical values of C_1 are shown in *Figure 3.5.1 Illustration of the C_1 coefficients for deckhouse and superstructure pressures*

= Where there is more than one deckhouse, the front of the most forward deckhouse will normally be considered exposed, whereas the back of this deckhouse will be non-exposed. Normally, the front of the deckhouse aft of this one will also be considered non-exposed.

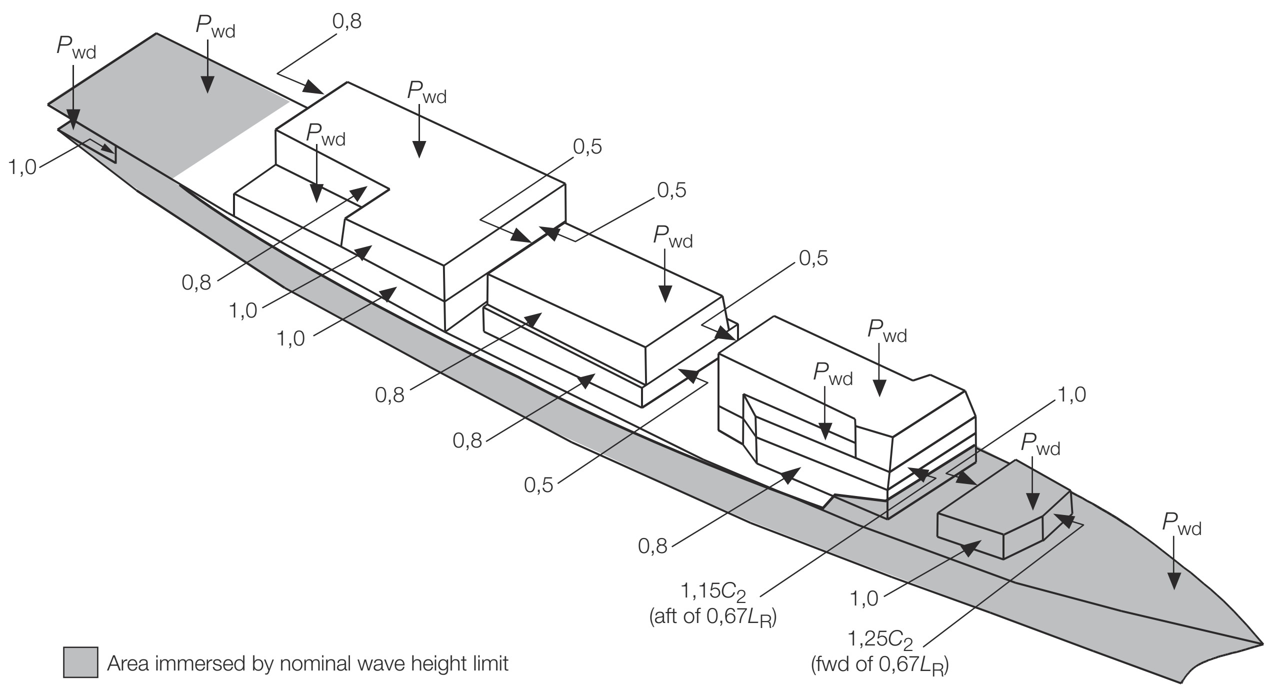


Figure 3.5.1 Illustration of the C_1 coefficients for deckhouse and superstructure pressures

5.6 Pressure height for deep tank bulkheads and boundaries, H_{tk}

5.6.1 The design lateral pressure height for tank and deep tank bulkheads and boundaries, H_{tk}, is to be taken as

H_{tk} = the distance, in m, from the baseline to half the distance from the top of the tank to the top of the overflow. For determination of the maximum head, the top of the overflow is to be taken as not less than 1,8 m above the crown of the tank, *see Figure 3.5.2 Pressure height for deep tank bulkheads*

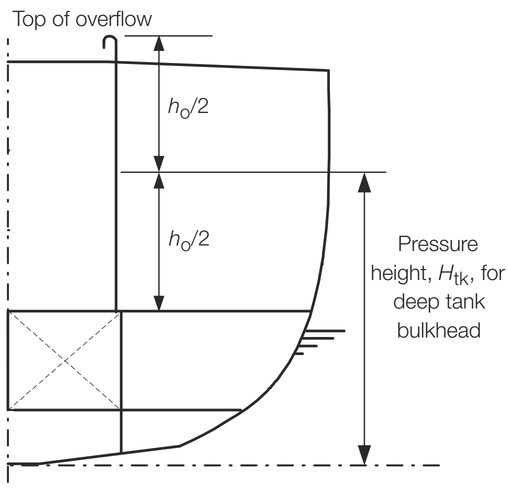


Figure 3.5.2 Pressure height for deep tank bulkheads

5.6.2 For tanks which are connected to a filling tank system, H_{tk} may be taken as the distance, in m, from the baseline to the highest point of the overflow pipe from the filling tank into the overflow tank. Consideration may need to be given to the pressure height for situations where any of the valves in the filling system may be closed. The transfer pump must feed only into the filling tank and must not be linked directly to the tanks.

5.6.3 In a filling tank system, suitable measures are to be provided such that the maximum design level in the system cannot be exceeded. Automatic shutdown measures are to ensure a fail safe arrangement to avoid overfilling the filling tank or the overflow tank. The overflow pipe is to be of sufficient size to ensure that the filling trunk is not overfilled.

5.7 Pressure height for watertight bulkheads and boundaries, H_{da}

5.7.1 The design lateral pressure height for watertight bulkheads and boundaries, H_{da}, is to be taken as

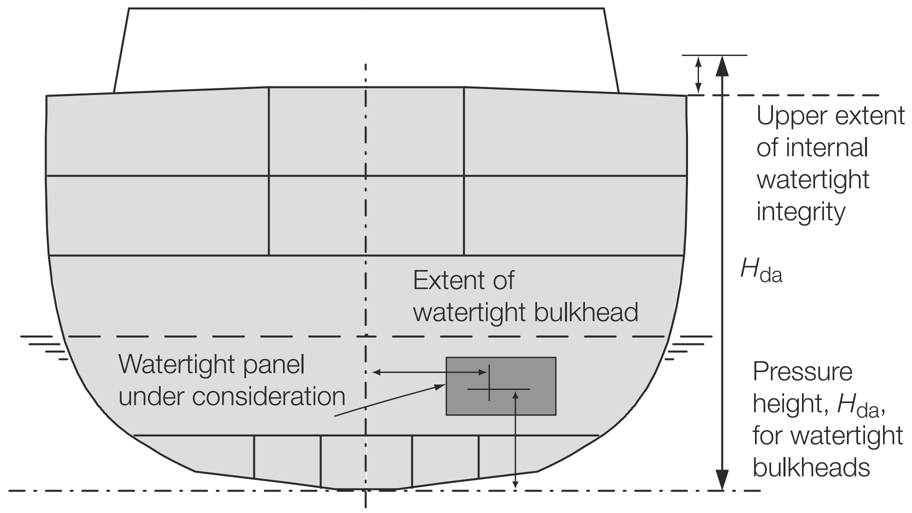
(a) for a watertight bulkhead design philosophy based on a SOLAS type approach, i.e. to the top of a watertight bulkhead deck or freeboard deck, *see Vol 1, Pt 3, Ch 2, 1.3 Watertight and weathertight integrity 1.3.8* and illustrated in *Figure 2.1.1* .

H_{da} = the vertical distance, in m, from baseline to a line 0,91 m above the top of the watertight bulkhead at side, *see Figure 3.5.3 Pressure height for watertight bulkheads*.

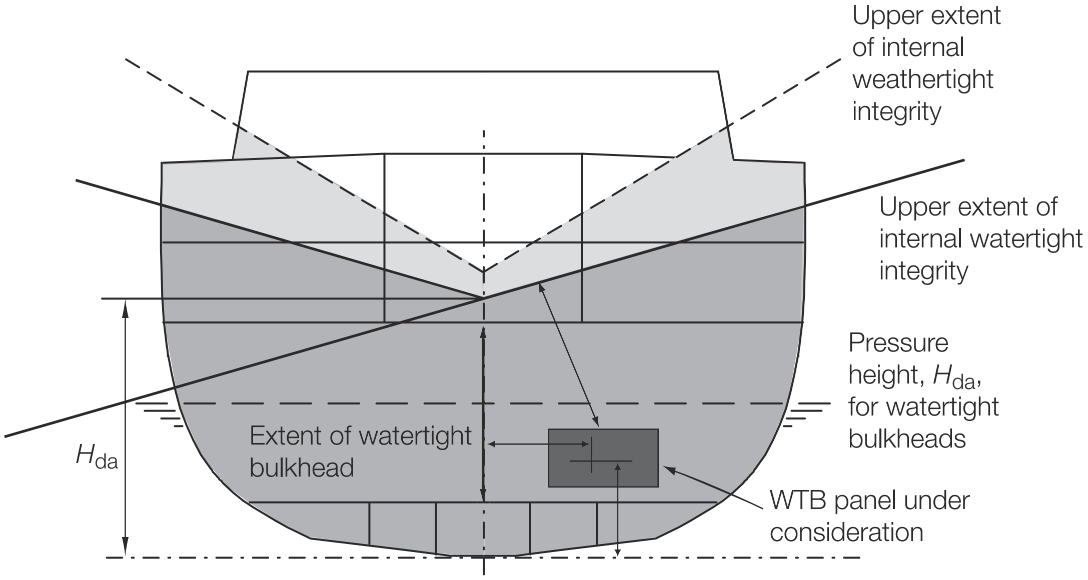
(b) for a watertight bulkhead design philosophy based on a standard which requires a damaged stability draft and heel envelope approach, e.g. the red risk line approach, *see Vol 1, Pt 3, Ch 2, 1.3 Watertight and weathertight integrity 1.3.9* and illustrated in *Figure 2.1.2* .

H_{da} = the distance, in m, from baseline to the damaged stability draft envelope at the centreline, *see Figure 3.5.3 Pressure height for watertight bulkheads*.

Note: The effect of lesser angles of heel in the damage situation may lead to an increase in the effective pressure height, especially in way of the forward end of the ship where it may be necessary to consider H_{da} based on a zero heel angle.



(a) Watertight subdivision based on a deck



(b) Watertight subdivision based on the limit of watertight integrity

Figure 3.5.3 Pressure height for watertight bulkheads

5.8 Design pressures for watertight and deep tank bulkheads and boundaries

5.8.1 The design normal pressure for bulkhead plating with stiffeners is to be considered separately for the plating and the stiffeners. The design normal pressure for the plating, P_{bhp}, is to be taken as follows:

Deep Tank

$\rho g (H_{tk} - z_p)$ kN/m^2

WT sub-division based on the head normal to the line of watertight integrity

maximum of

$10((H_{da} - z_p) \cos\theta + y_p \sin\theta)$ kN/m^2

$10(H_{da} - z_p)$ kN/m^2

where

ρ = density of fluid, in tonnes/m^3, and is not to be taken as less than 1,025

z_p = distance above the baseline of a point one-third of the height, above the lower edge, of the plate strake under consideration, z_p is illustrated in *Figure 3.5.4 Z, distance above baseline for pressure head for plating with horizontal stiffeners* for horizontally stiffened plating and *Figure 3.5.5 Z, distance above baseline for pressure head for plating head for plating with vertical stiffeners* for vertically stiffened plating

y_p = distance from the centreline of the mid-breadth of the plate strake under consideration, y_p, is always to be taken as positive

θ = the stipulated damaged stability heel angle, *see also Vol 1, Pt 3, Ch 2, 1.3 Watertight and weathertight integrity* For a SOLAS type approach, θ is normally to be taken as 0,0.

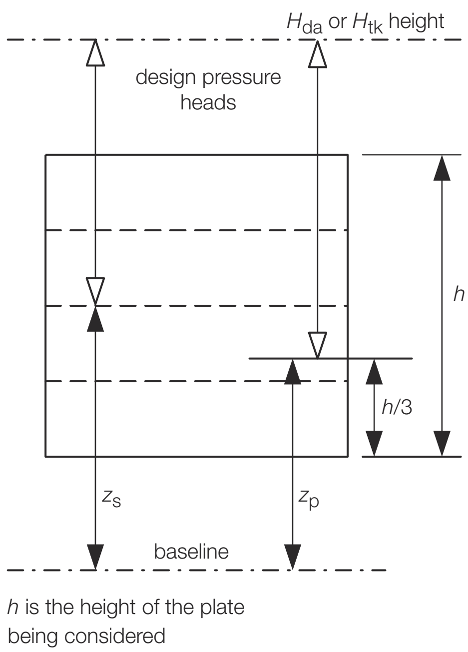


Figure 3.5.4 *Z*, distance above baseline for pressure head for plating with horizontal stiffeners

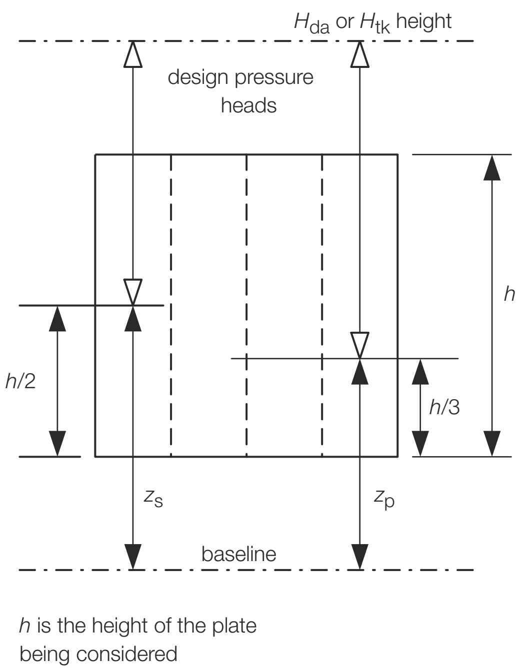


Figure 3.5.5 *Z*, distance above baseline for pressure head for plating head for plating with vertical stiffeners

5.8.2 The design normal pressure for the stiffener, P_{bhs}, is to be taken as follows:

Deep Tank

$\rho g (H_{tk} - z_s)$ kN/m^2 (Deep Tank)

WT sub-division

maximum of:

$10((H_{da} - z_s) \cos \theta + y_s \sin \theta)$ kN/m^2

$10(H_{da} - z_s)$ kN/m^2

where

z_s = distance above base of the mid span of the vertical stiffener under consideration, *see Figure 3.5.5 Z, distance above baseline for pressure head for plating head for plating with vertical stiffeners*

or

z_s = distance above base of the mid span of the horizontal stiffener under consideration, *see Figure 3.5.4 Z, distance above baseline for pressure head for plating with horizontal stiffeners*

y_s = distance from the centreline of the mid span of the stiffener under consideration, y_s is always to be taken as positive

ρ = density of fluid, in tonnes/m^3, and is not to be taken as less than 1,025.

5.8.3 The appropriate design criteria are to be applied to the bulkhead plating and stiffeners, *see Vol 1, Pt 6, Ch 5 Structural Design Factors* It is not permissible to use watertight criteria for a deep tank design head.

5.8.4 The design impulse pressure, IP_{bh}, for the bulkhead plating and stiffeners may be ignored, unless these members are likely to be subjected to significant sloshing loads or similar. In this case it will be necessary to determine the sloshing loads using a suitable direct calculation procedure.

5.9 Design pressures for collision bulkheads

5.9.1 The design lateral pressure height for collision bulkheads, H_{cb}, is to be taken as:

H_{cb} = the vertical distance, in m, from the baseline to 0,91 m above the uppermost point of the collision bulkhead.

5.9.2 The design normal pressure for the collision bulkhead plating, P_{bhp}, is to be taken as:

$$P_{bhp} = 10\,(H_{cb} - z_p)\ \text{kN/m}^2$$

where

z_p = distance above baseline of a point one third of the height, above the lower edge, of the plate strake under consideration.

5.9.3 The design normal pressure for bulkhead stiffeners, P_{bhs}, is to be taken as:

$$P_{bhs} = 10\,(H_{cb} - z_s)\ \text{kN/m}^2$$

where

z_s = distance above base of the mid-span of the vertical stiffener under consideration, *see Figure 3.5.5 Z, distance above baseline for pressure head for plating head for plating with vertical stiffeners*

= or

z_s = distance above base of the mid-span of the horizontal stiffener under consideration, *see Figure 3.5.4 Z, distance above baseline for pressure head for plating with horizontal stiffeners*

5.9.4 The collision bulkheads are to be designed to the deep tank design criteria specified in *Vol 1, Pt 6, Ch 5 Structural Design Factors*

5.9.5 If there is a design requirement for the ship to be able to remain operational after an incident which results in the collision bulkhead becoming the primary watertight boundary to the sea, then it will be necessary to design the collision bulkhead using the pressures for the shell envelope, P_s, given in *Vol 1, Pt 5, Ch 3, 3 Loads on shell envelope* and the shell envelope design criteria. It will also be necessary to consider the effects of wave impact pressures, *see Vol 1, Pt 5, Ch 3, 4.3 Bow flare and wave impact pressures, IPbf*, using the design speed requirement after damage.

5.10 Design loads for RSA notation assessment

5.10.1 The capability of transverse bulkheads, longitudinal bulkheads, watertight decks and other structure to withstand any additional loads as a consequence of damage, e.g. sloshing loads on watertight bulkheads, may need to be specially considered. Pressure heads consistent with draughts and heel angles determined from the damage stability analyses are to be used for local scantling assessment.

5.10.2 Where watertight boundaries for damage control purposes are specified in the subdivision and stability standard, the nominated bounding decks are to be assigned as watertight *see Vol 1, Pt 6, Ch 3, 10 Deck structures*. The pressure heads used in the assessment of damage control decks are to be the greater of that determined from the Rules or that specified by the Owner.

5.10.3 The local design loads for structures subjected to additional loading as a consequence of structural damage are to be taken as specified in this Chapter except that the wave height factor, f_{Hs}, may be reduced, to account for the lesser environmental requirements, as follows:

f_{Hs} = may be reduced by a factor of 1,85

where

f_{Hs} = is defined in *Vol 1, Pt 5, Ch 3, 1.2 Environmental conditions*.

5.10.4 Where local strength issues need to be considered, the following local loads are to be applied in the evaluation contained in *Vol 1, Pt 6, Ch 4, 4.1 Application*:

- Hydrostatic load due to flooding taking account of the increase in local draft.

- Wave and inertial loads in the damaged condition, derived using the reduction factor given in *Vol 1, Pt 5, Ch 3, 5.10 Design loads for RSA notation assessment 5.10.3*.
- Local loads on watertight divisions as a consequence of flooding. For the evaluation of local loads on watertight divisions, the standard design pressure, H_{da} (*see Vol 1, Pt 5, Ch 3, 5.7 Pressure height for watertight bulkheads and boundaries, Hda*) may be applied. Alternatively the external hydrostatic and wave pressure load, P_s, may be applied using the reduction factor given in *Vol 1, Pt 5, Ch 3, 5.10 Design loads for RSA notation assessment 5.10.3*.
- Wave impact loads need not be considered unless a significant operational requirement is necessary following damage.

5.11 Design pressure for magazine decks and bulkheads

5.11.1 For magazine structure which is assessed in accordance with Pt 4, Ch 1,6.4 the quasi-static design pressure is to be taken as follows:

$$P_{mag} = 2,25 \left(\frac{W_e}{V}\right)^{0,72} \times 10^3 \text{ kN/m}^2$$

where

W_e = weapon equivalent weight of TNT, in kg

V = free compartment volume, in m^3.

5.11.2 For magazines below the limit of watertight integrity the design pressure, P_{mag}, is not to be taken as less than the design pressure for watertight bulkheads and boundaries, plating and stiffening, *see Vol 1, Pt 5, Ch 3, 5.8 Design pressures for watertight and deep tank bulkheads and boundaries*.

■ Section 6
Other local loads

6.1 General

6.1.1 This section gives formulations for design pressure loads for shell closing appliances and requirements for gravity and inertial loads due to equipment, payload, cargo, etc. acting on ramps and lifting appliances.

6.2 Loads for ramps and lifts, P_{ra}

6.2.1 The loads acting on ramps and lifts intended to be used at sea, P_{ra}, is to be derived as follows:

$$P_{ra} = W_{cd} (1 + f_d (a_z + a_{ra})) \text{ kN/m}^2$$

where

W_{cd} = is the equivalent static pressure exerted by the cargo on the ramp or lift as specified by the designer in kN/m^2.

a_z = is the non dimensional vertical acceleration given in *Vol 1, Pt 5, Ch 3, 2.3 Design accelerations 2.3.2*

a_{ra} = maximum acceleration of the lift, *see Vol 1, Pt 5, Ch 3, 2.3 Design accelerations*

f_d = duty factor for the lift or ramp

= 2,0 for operation with personnel

= 1,5 otherwise.

6.2.2 If the hoisting speed of the ramp or lift is such that the acceleration of the lift will cause an increase in the forces acting on the lift, then this acceleration term should be included.

6.2.3 Where the lift or ramp is designed to operate totally or partially under water, then due consideration is to be taken of the additional forces applied to the lift or ramp as a direct consequence of the water environment, e.g. added mass and velocity dependent damping forces.

6.3 Loads for windows and side scuttles in deckhouses and superstructures, P_{wi}

6.3.1 The design pressure, P_{wi}, for windows and side scuttles in deckhouses and superstructures is to be taken as:

$$P_{wi} = W_1 P_s \text{ kN/m}^2$$

In no case is the design pressure to be taken less than $P_{wi,min}$ as given by:

$$P_{wi,min} = W_1 (10 + 0{,}04 L_R) \text{ kN/m}^2$$

Where $P_{wi,min}$ need not be taken as greater than 15 kN/m^2 for the third tier of deckhouses or superstructures and above.

where

$$W_1 = 1{,}33 C_1$$

P_s is to be taken at the height of the deck below the window or side scuttle, *see* 3.2

C_1 is defined in *Vol 1, Pt 5, Ch 3, 5.5 Loads for deckhouses, bulwarks and superstructures, Pdh 5.5.1*.

6.4 Loads for masts

6.4.1 The inertia forces resulting from the motions of the ship are to be calculated in accordance with *Vol 1, Pt 5, Ch 3, 2 Motion response* and combined with the wind force defined below acting in the most onerous direction for the case being considered.

6.4.2 Where applicable the additional inertia forces due to ice accretion are to be derived in accordance with *Vol 1, Pt 5, Ch 2, 4.6 Ice accretion* and included in the calculations.

6.4.3 The wind pressure, p, acting on the structure is given by:

$$p = \frac{V^2}{1630} \text{ kN/m}^2$$

where

V = wind speed, in m/s. To be taken as 63 m/s unless otherwise specified.

6.4.4 The wind force, F_w, on the mast structure is given by:

$$F_w = A\, p\, C_f \text{ kN}$$

where

A = the effective area of the structure concerned, i.e. the solid area projected on to a plane perpendicular to the wind direction, in m^2

p = wind pressure, in N/m^2

C_f = force coefficient in the direction of the wind, as defined in *Table 3.6.1 Force coefficient (Cf)* .

Table 3.6.1 Force coefficient (*Cf*)

Type	Description		Aerodynamic slenderness l/b or l/D					
			5	10	20	30	40	50
Individual members	Rolled sections, rectangles, hollow sections, flat plates, box sections with b or d less than 0,5 m		1,30	1,35	1,60	1,65	1,70	1,80
	Circular sections, where	$DV_s < 6$ m^2/s	0,75	0,80	0,90	0,95	1,00	1,10
		$DV_s \geq 6$ m^2/s	0,60	0,65	0,70	0,70	0,75	0,80
		b/d						
	Box sections with *b* or *d* greater than 0,5 m		≥2,00	1,55	1,75	1,95	2,10	2,20
			1,00	1,40	1,55	1,75	1,85	1,90
			0,50	1,00	1,20	1,30	1,35	1,40
			0,25	0,80	0,90	0,90	1,00	1,00
Single lattice frames	Flat sided sections		1,70					
	Circular sections, where	$DV_s < 6$ m^2/s	1,20					
		$DV_s \geq 6$ m^2/s	0,80					
Plated structure	Plated structures on ground or solid base (air flow beneath structure prevented)		1,10					

Symbols

l = height of mast, in metres
D = diameter of mast, in metres
V_s = wind speed, in m/s
b = breadth of box section, in metres
d = depth of box section, in metres

6.5 Hangar doors and other large doors in superstructures

6.5.1 The design pressure, P_{ds}, for large doors in superstructures is to be taken as:

$$P_{ds} = C_1 P_s \text{ kN/m}^2$$

where

P_s is to be taken at the height of the deck on which the doors sits, *see Vol 1, Pt 5, Ch 3, 3.2 Combined hydrostatic and hydrodynamic pressure on the shell plating, Ps*

C_1 is defined in *Vol 1, Pt 5, Ch 3, 5.5 Loads for deckhouses, bulwarks and superstructures, Pdh 5.5.1*.

■ Section 7
Ice loads

7.1 General

7.1.1 A half or full icing allowance in accordance with *Vol 1, Pt 5, Ch 2, 4 Guidance for ice environment* is to be included in the local load calculations of plating and stiffed panels of ships that are required to operate for extended periods in areas where ice accretion is expected.

■ *Section 1* General

1.1 Introduction

1.1.1 The global design loads detailed in this Chapter are to be used in conjunction with *Vol 1, Pt 6 Hull Construction in Steel* to determine the global hull strength requirements. The application of the global design loads is given in *Vol 1, Pt 6, Ch 4 Hull Girder Strength*.

1.1.2 Flowcharts showing the procedures for the specification of the global design loads are shown in *Figure 4.1.1 Procedure for the specification of global design loads*.

1.1.3 The global design loads are divided into the following categories:

(a) Hull girder loads.

The types of hull girder loads which are to be considered for strength purposes in the initial design assessment are distinguished on the basis of their frequency of occurrence and are defined as follows:

(i) Still water shear forces and associated bending moments arising from static mass distribution and buoyancy forces, *see Vol 1, Pt 5, Ch 4, 2 Still water global loads*.
(ii) Low frequency vertical wave shear forces and associated bending moments arising from hydrodynamic forces.
(iii) High frequency dynamic shear forces and associated bending moments arising from slamming events.

The derivation of the hull girder loads is given in *Vol 1, Pt 5, Ch 4, 3 Global hull girder loads*.

(b) Extreme hull girder loads.

The loads to be considered for extreme hull girder strength purposes are used to assess the hull girder structural capability to withstand extreme sea states. The derivation of the extreme hull girder loads is given in *Vol 1, Pt 5, Ch 4, 4 Extreme hull girder loads*.

(c) Hull girder loads for residual strength assessment.

The loads to be considered for residual strength purposes are used to assess the structural capability of the ship after damage to withstand moderately severe sea states. The derivation of the residual strength hull girder loads is given in *Vol 1, Pt 5, Ch 4, 5 Residual strength hull girder loads*.

1.1.4 Alternative methods of establishing the global load and design criteria will be specially considered, provided that they are based on model tests, full scale measurements or other generally accepted theories. In such cases, full details of the methods used and the results are to be provided when plans are submitted for approval.

1.2 Definitions and symbols

1.2.1 L_R, B, B_{WL}, D and T are defined in *Vol 1, Pt 3, Ch 1, 5 Definitions*. F_n and Δ are defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions 1.3.2* and *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions 1.3.1* respectively. Displacement mode and non-displacement mode are defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions*.

1.2.2 For longitudinal strength calculations of vertical shear force and bending moment, downward loads are to be taken as positive values and are to be integrated in the forward direction from the aft end of the ship. Shear force is positive when the algebraic sum of all vertical forces aft of the position is positive. Hogging bending moments are to be taken as positive values.

1.3 Direct calculation procedures

1.3.1 The still water longitudinal strength values are to be derived using a suitable longitudinal strength calculation system.

1.3.2 In direct calculation procedures capable of deriving the wave induced loads on the ship account is to be taken of the ship's actual form and weight distribution.

1.3.3 Lloyd's Register's (hereinafter referred to as 'LR') direct calculation method of the long term wave induced loads involves derivation of response to regular waves by strip theory, short-term response to irregular waves using the sea spectrum concept, and long-term response predictions using statistical distributions of sea states. Other direct calculation methods submitted for approval are normally to contain these three elements and produce similar and consistent results when compared with LR's methods.

1.3.4 The long term response predictions are to be based on probability of 10^{-8}. The LR long term prediction method produces values which have a low statistical probability of occurring taking into account many factors. These factors include:

- The operating life of the vessel, normally the operating life is taken as 20 years which is assumed to correspond to 10^8 wave encounters.
- The mission profile of the vessel.
- Different loading conditions.
- The effect of different wave headings on ship motions.

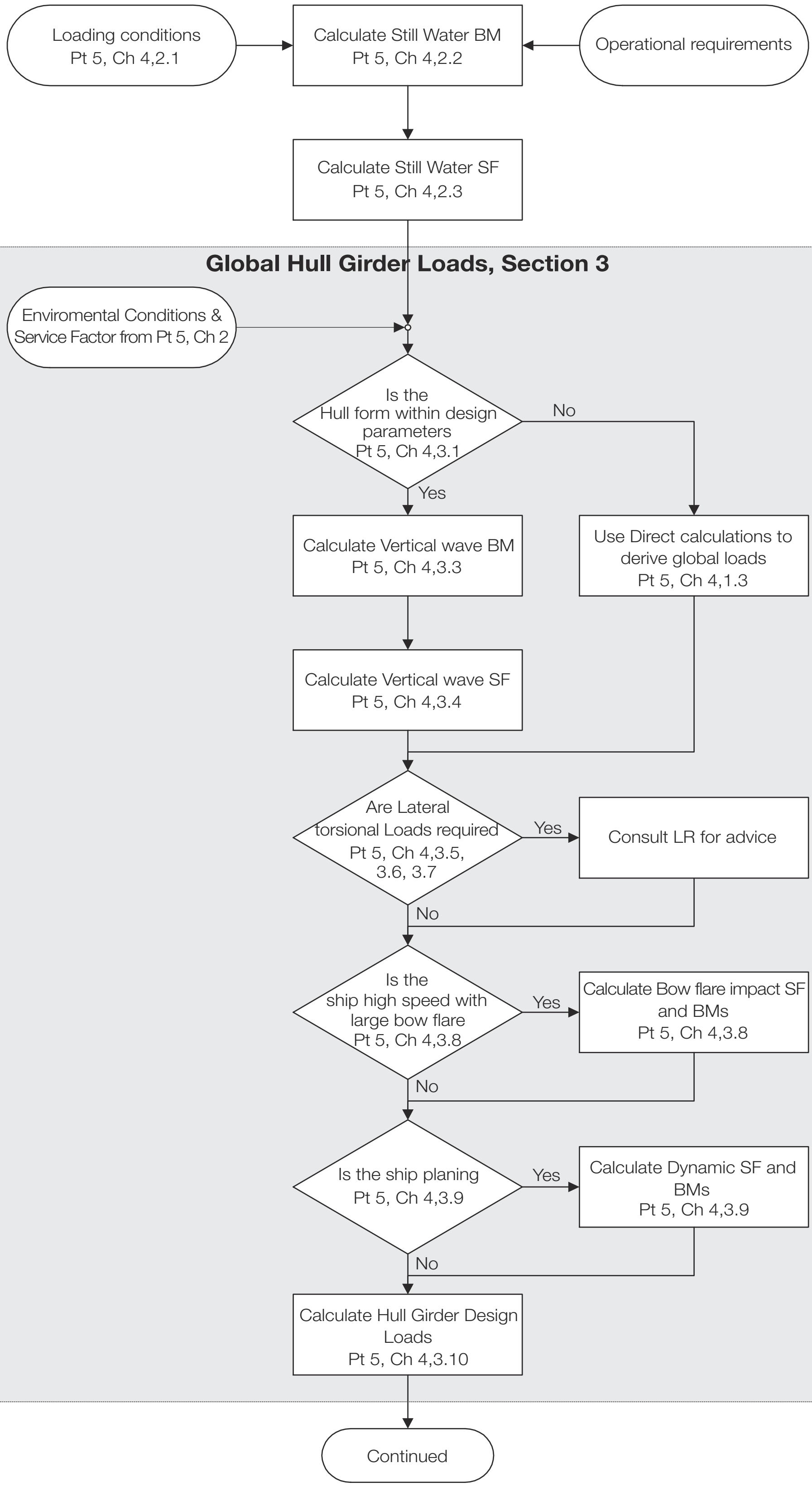


Figure 4.1.1 Procedure for the specification of global design loads

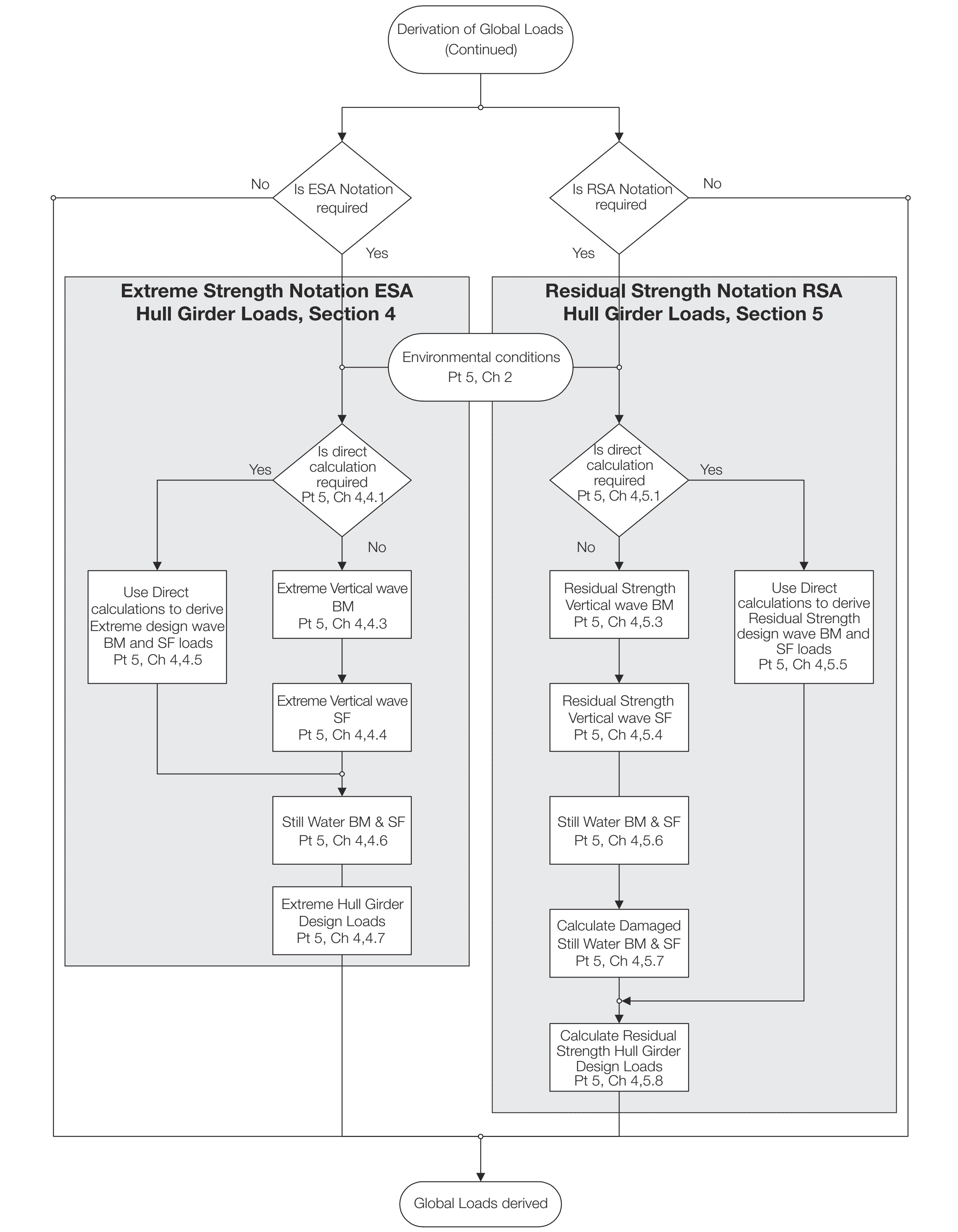


Figure 4.1.2 Procedure for the specification of global design loads *(continued)*

1.4 Information required

1.4.1 In order that an assessment of the longitudinal strength requirements can be made, the following information is to be submitted, in LR's standard format where appropriate:

(a) General arrangement and capacity plan or list showing details of the volume and position of centre of gravity of all tanks, spaces and compartments.
(b) Bonjean data, in the form of tables or curves, for at least 21 equally spaced stations along the hull together with a lines plan and/or tables of offsets.
(c) Details of the calculated lightweight and its distribution.
(d) Details of the weights and centres of gravity of all deadweight items for each of the main loading conditions.
(e) Calculated still water bending moments and shear forces and the proposed design envelopes. Calculated wave and dynamic bending moment and shear force values.

1.4.2 It is recommended that this information be submitted in the form of a preliminary Loading Manual or Stability Information Book including: specification of operational requirements, hydrostatic data, details of loading conditions, etc. It may also be necessary to submit a summary of the damage stability analysis.

■ *Section 2* Still water global loads

2.1 General

2.1.1 The still water bending moments and shear force distributions are to be derived using a suitable direct calculation method for a range of loading conditions which cover the operational envelope of the ship.

2.1.2 In general, loading conditions based on amount of fuel, fresh water, stores and payload at departure, arrival and during special operations are to be considered. Loading conditions representing special operational requirements are also to be considered.

2.1.3 As a minimum the following conditions are to be considered in deriving the maximum hogging and sagging still water bending moment and shear force envelopes:

- Deep draught (departure) condition with no growth margin.
- Light draught (arrival) condition with no growth margin.
- Deep draught condition with full growth margin.
- Light draught condition with full growth margin.
- Maximum and minimum operating draught conditions, if different to the above.
- Ballast conditions, where appropriate.
- Any special mid-voyage conditions caused by changes in payload or ballast distribution.
- Other special loading conditions, e.g. Emergency evacuation or similar emergency scenario conditions, heavy payloads or cargo, deck cargo conditions, etc. where applicable.

2.1.4 For special loading conditions which may only be required in restricted operational areas, a reduced service area factor, f_S, may be allowable, *see Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments 3.3.1*.

2.1.5 If the still water bending moment and shear force envelope approach is not appropriate, (as a consequence of the envelope being too severe due to one or two special conditions distorting the envelope) then individual consideration of the bending moment and shear force will be necessary.

2.1.6 A full or half icing allowance in accordance with *Vol 1, Pt 5, Ch 2, 4 Guidance for ice environment* is to be included in the still water bending moment and shear force calculations.

2.1.7 To account for miscellaneous fittings such as stanchions and rails an additional 5 per cent should be added to the total ice weight calculated for both full and half icing allowances.

2.2 Still water bending moments

2.2.1 The design still water hogging and sagging bending moment distribution envelope, M_S, is to be taken as the maximum sagging (negative) and maximum hogging (positive) still water bending moments, in kN m, calculated at each position along the ship. The maximum moments from all loading conditions are to be used to define the still water bending moment distribution envelope.

2.2.2 It is normal for ships which have low deadweight requirements, e.g. frigates, to have a bending moment distribution envelope which is always hogging. In this case the maximum sagging bending moment envelope may be taken as the minimum hogging bending moment.

2.3 Still water shear forces

2.3.1 The design still water shear force distribution envelope, Q_S, is to be taken as the maximum positive and negative shear force values, in kN, calculated at each position along the ship. The maximum shear forces from all loading conditions, *see Vol 1, Pt 5, Ch 4, 2.2 Still water bending moments*, are to be used to define the still water shear force distribution envelope.

2.3.2 It is recommended that the minimum shear force value over the midships region should not be less than 50 per cent of the maximum value.

■ *Section 3*
Global hull girder loads

3.1 General

3.1.1 The global hull girder loads specified here are applicable to all displacement mono-hull naval ships as defined in *Vol 1, Pt 1, Ch 2, 2.2 Definitions 2.2.6*. These loads are to be used in the hull girder strength assessment given in *Vol 1, Pt 6, Ch 3 Scantling Determination*.

3.1.2 Individual consideration based on direct calculation procedures will generally be required for ships having one or more of the following characteristics:

(a) Froude number > 0,8 (based on V_{sp}, *see Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions 1.3.1*)

$L_R/B_{WL} \leq 5$, or $B_{WL}/D \geq 2{,}5$

Unusual hull weight distribution

Unusual type or design.

3.2 Environmental conditions

3.2.1 The environmental conditions given in *Vol 1, Pt 5, Ch 2 Environmental Conditions* are to be used in the derivation of the global hull girder loads.

3.3 Vertical wave bending moments

3.3.1 The minimum value of vertical wave bending moment, M_W at any position along the ship may be taken as follows:

$$M_W = F_f D_f M_o \text{ kNm}$$

where

(a) F_f is the hogging, F_{fH}, or sagging, F_{fS}, correction factor based on the amount of bow flare, stern flare, length and effective buoyancy of the aft end of the ship above the waterline.

(b) F_{fS} is the sagging (negative) moment correction factor and is to be taken as

$F_{fS} = -1{,}10\, R_A^{0,3}$	for values of $R_A \geq 1{,}0$
$F_{fS} = -1{,}10$	for values of $R_A < 1{,}0$

An area ratio value of 1,0 results in a sagging correction factor of –1,10.

(a) FfH is the hogging (positive) moment correction factor and is to be taken as

$$F_{\text{fH}} = \frac{1,9C_{\text{bl}}}{(C_{\text{bl}} + 0,7)}$$

R_A is an area ratio factor, *see Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments 3.3.2*.

D_f = the longitudinal distribution factor
= 0 at aft end of L_R
= 1,0 between 0,4L_R and 0,65L_R
= 0 at forward end of L_R
= Intermediate values of D_f are to be determined by linear interpolation

M_o = $0{,}1 L_f f_s L_R^2 B_{WL} (C_{b1} + 0{,}7)$ kNm

L_f = $0,0412L_{\text{R}} + 4,0 \quad for L_{\text{R}} \leq 90\text{m}$
= $10,75 - \left(\frac{300 - L_{\text{R}}}{100}\right)^{1,5} for L_{\text{R}} > 90\text{m}$
= $10,75 \quad for L_{\text{R}} > 300\text{m}$
= $10,75 - \left(\frac{L_{\text{R}-350}}{150}\right)^{1,5} \quad for L_{\text{R}} > 350\text{m}$

f_s = Service area factor applicable to the Service Area Notation. To be specially considered depending upon the required areas of operation and in any event should be not less than 0,5

For unrestricted sea-going service f_s = 1,0, for other Service Areas Notations, *see Vol 1, Pt 5, Ch 2, 2.4 Service Area factors*

B_{WL} = maximum waterline breadth, *see Vol 1, Pt 5, Ch 4, 1.2 Definitions and symbols 1.2.1*

C_{b1} = C_b but is not to be taken less than 0,60

C_b = the block coefficient as defined in *Vol 1, Pt 3, Ch 1, 5 Definitions*

3.3.2 The area ratio factor, R_A, for the combined stern and bow shape is to be derived as follows:

$$R_{\text{A}} = \frac{30(A_{\text{BF}} + 0,5A_{\text{SF}})}{L_{\text{R}}B_{\text{WL}}}$$

where

A_{BF} = is the bow flare area, in m^2, *see Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments 3.3.3*

A_{SF} = is the stern flare area, in m^2, *see Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments 3.3.4*

3.3.3 The bow flare area, A_{BF}, is illustrated in *Figure 4.3.1 Deviation of bow and stern flare areas* and may be derived as follows:

A_{BF} = $A_{UB} - A_{LB}$ m^2

where

A_{UB} = half the water plane area at a waterline of $T_{C,U}$ of the bow region of the hull forward of 0,8L_R from the AP

where

A_{LB} = half the water plane area at the design draught of the bow region of the hull forward of 0,8 L_R from the AP.

Note the AP is to be taken at the aft end of the Rule length, L_R

The design draught is to be taken as T, *see Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions 1.3.1*

Alternatively the following formula may be used

A_{BF} = $0{,}05\, L_R\, (b_0 + 2\, b_1 + b_2) + b_0\, a/2$ m^2

where

b_0 = projection of $T_{C,U}$ waterline outboard of the design draught waterline at the FP, in metres, *see Figure 4.3.1 Deviation of bow and stern flare areas*

b_1 = projection of $T_{C,U}$ waterline outboard of the design draught waterline at 0,9L_R from the AP, in metres

b_2 = projection of $T_{C,U}$ waterline outboard of the design draught waterline at 0,8L_R from the AP, in metres

a = projection of $T_{C,U}$ waterline forward of the FP, in metres

$T_{C,U}$ = is a waterline taken $L_f/2$ m above the design draught

L_f is given in *Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments 3.3.1*

For ships with large bow flare angles above the $T_{C,U}$ waterline the bow flare area may need to be specially considered.

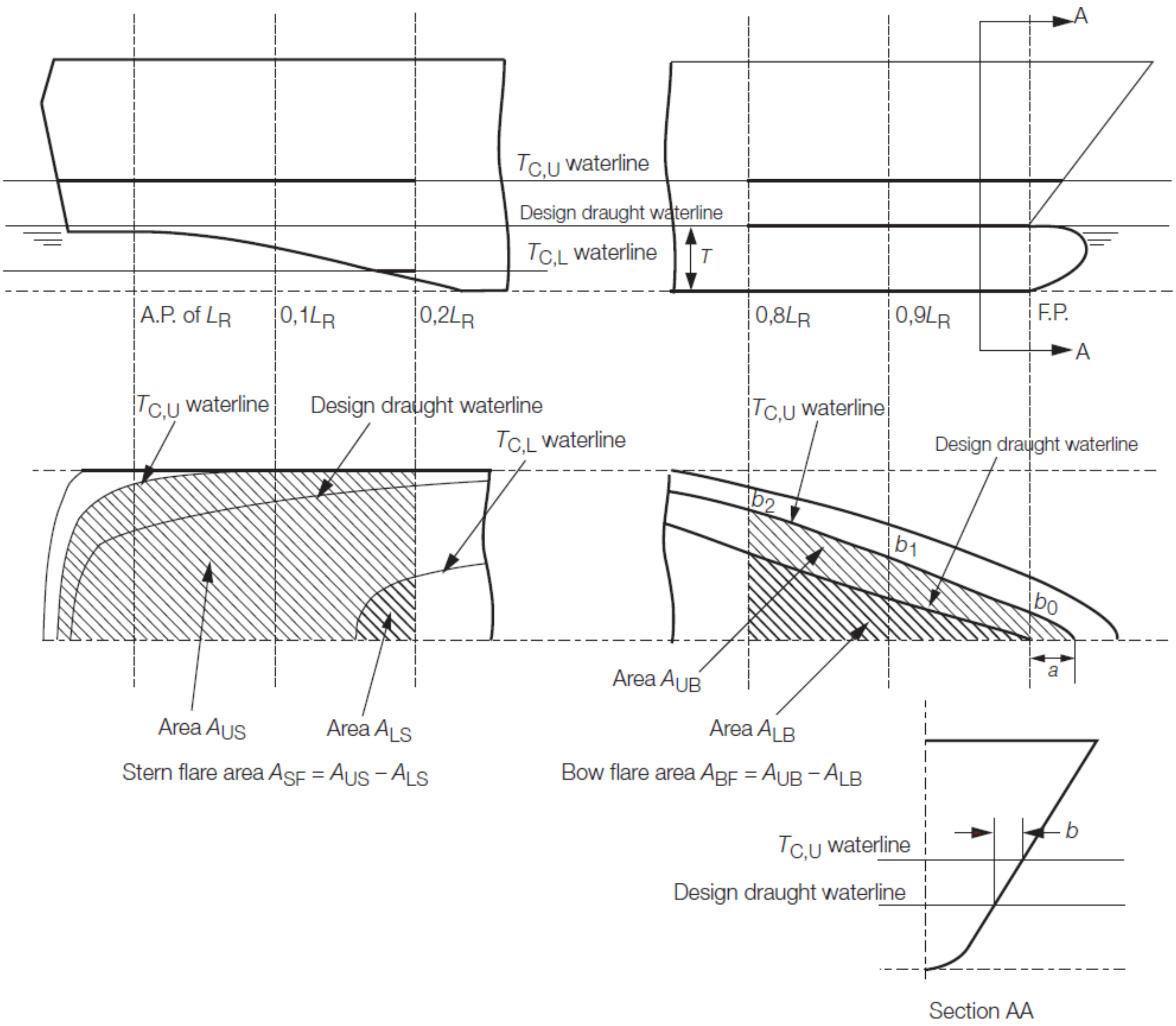


Figure 4.3.1 Deviation of bow and stern flare areas

3.3.4 The stern flare area, A_{SF}, is illustrated in *Figure 4.3.1 Deviation of bow and stern flare areas* and is to be derived as follows:

$$A_{SF} = A_{US} - A_{LS} \text{ m}^2$$

where

A_{US} = half the water plane area at a waterline of $T_{C,U}$ of the stern region of the hull from aft to 0,2 L_R forward of the *AP*

A_{LS} = half the water plane area at a waterline of $T_{C,L}$ of the stern region of the hull from aft to 0,2 L_R forward of the *AP*

$T_{C,L}$ = is a waterline taken $L_f/2$ m below the design draught

$T_{C,L}$ = $T - L_f$ m ^{2}

For ships with tumblehome in the stern region, the maximum breadth at any waterline less than $T_{C,U}$ is

to be used in the calculation of A_{US}. The effects of appendages including bossings are to be ignored in the calculation of A_{LS}.

3.3.5 Alternatively, for frigate and destroyer type ships the hogging and sagging vertical wave bending moments and shear forces may be derived from long term 'in-service' measurements of a series of ships with similar hull forms, mass distributions and areas of operation. Typically this will be based on a static wave balance approach. The longitudinal distribution of the vertical wave bending moment is to be taken in accordance with the longitudinal distribution factor, D_f.

3.3.6 The vertical wave bending moments and associated shear forces are not to be taken as less than that given by *Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments 3.3.1* and *Vol 1, Pt 5, Ch 4, 3.4 Vertical wave shear forces 3.4.1*.

3.3.7 Direct calculation methods may be used to derive the vertical wave bending moments, *see Vol 1, Pt 5, Ch 4, 1.3 Direct calculation procedures*

3.3.8 The sagging correction factor, f_{fS}, in the vertical wave bending moment formulation in *Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments 3.3.1* may be derived by direct calculation methods. Appropriate direct calculation methods may include a combination of long term ship motion analysis, non linear ship motion analysis and static balance on a wave crest or trough.

3.4 Vertical wave shear forces

3.4.1 The wave shear force, Q_W, at any position along the ship is given by:

$$Q_W = \frac{3K_f M_o}{L_R} \text{ kN}$$

where

= K_f is to be taken as follows; *see also* Fig.*Figure 4.3.2 Shear force factor K_f*

(a) Positive shear force:

K_f = 0 at aft end of L_R
= $+0,836F_{fH}$ between $0,2L_R$ and $0,3L_R$
= $+0,65F_{fH}$ between $0,4L_R$ and $0,5L_R$
= $–0,65F_{fS}$ between $0,5L_R$ and $0,6L_R$
= $–0,91F_{fS}$ between $0,7L_R$ and $0,85L_R$
= 0 at forward end of L_R

(a) Negative shear force:

K_f = 0 at aft end of L_R
= $+0,836F_{fS}$ between $0,15L_R$ and $0,3L_R$
= $+0,65F_{fS}$ between $0,4L_R$ and $0,5L_R$
= $–0,65F_{fH}$ between $0,5L_R$ and $0,6L_R$
= $–0,91 F_{fH}$ between $0,7L_R$ and $0,85L_R$
= 0 at forward end of L_R

Intermediate values are to be determined by linear interpolation.

M_o, F_{fH} and F_{fS} are defined in *Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments 3.3.1*.

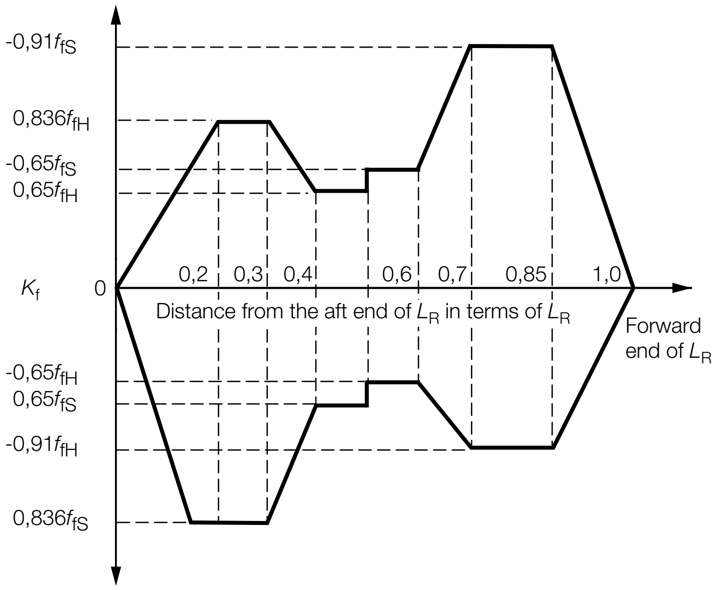


Figure 4.3.2 Shear force factor K_f

3.4.2 The direct calculation method used to derive the vertical bending moments may also be used to derive the vertical shear forces, *see Vol 1, Pt 5, Ch 4, 1.3 Direct calculation procedures*.

3.5 Lateral wave bending moments

3.5.1 If considered necessary by LR, the effects of lateral bending moments may need to be considered. Normally this will only be required for ships with extreme hull forms, multihulls, unusual structural configurations or arrangements or particular loading conditions or operational modes which are likely to result in significant lateral stresses.

3.6 Lateral wave shear forces

3.6.1 If considered necessary by LR, the effects of lateral shear forces may need to be considered. Normally this will only be required for ships with extreme hull forms, multihulls, unusual structural configurations or arrangements or particular loading conditions or operational modes which are likely to result in significant lateral stresses.

3.7 Torsional moments

3.7.1 If considered necessary by LR, the effects of torsional moments may need to be considered. Normally this will only be required for ships with extreme hull forms, multihulls, unusual structural configurations or arrangements or particular loading conditions or operational modes which are likely to result in significant torsional stresses.

3.8 Bow flare impact global loads

3.8.1 The requirements of this section are applicable to fast ships operating in the displacement mode that satisfy the following requirements:

(a) speed V_{sp} > 17,5 knots

bow shape factor ψ > 0,15

where

$$\psi = \frac{100 A_b K_{fr}}{L^{1,5}{}_R B_{WL}}$$

A_b = bow flare area, *see Vol 1, Pt 5, Ch 4, 3.8 Bow flare impact global loads 3.8.3*

where

k_{fr} = bow freeboard correction factor

k_{fr} = $\dfrac{6}{h_{fr}}$ but is to be not less than 0,5 nor greater than 1,5

h_{fr} = freeboard height to the upper deck measured at the FP, in metres

3.8.2 For ships with knuckles in the bow flare region above which the hull is nearly vertical or exhibits tumblehome, the values of h_{fr} and A_b are normally to be based on the bow flare region below the knuckle

L_R and B_{WL} are as defined in *Vol 1, Pt 5, Ch 4, 1.2 Definitions and symbols 1.2.1*

V_{sp} is defined in *Vol 1, Pt 5, Ch 3, 1.3 Symbols and definitions*

3.8.3 The bow flare area is normally to be derived as follows:

A_b = $0{,}05L_R (a_0 + 2a_1 + a_2) + a_0 b/2$ m^2

where

a_0 = projection of deck at waterline at the FP, in metres

a_1 = projection of deck at waterline at $0{,}9L_R$, in metres

a_2 = projection of deck at waterline at $0{,}8L_R$, in metres

b = projection of upper deck at waterline from the FP to stem, in metres

see Figure 4.3.3 Derivation of bow shape.

L_R is given in *Vol 1, Pt 5, Ch 4, 1.2 Definitions and symbols 1.2.1*

3.8.4 The dynamic sagging bending moment due to bow flare impact loads, M_{BF}, is given by the following:

M_{BF} = $-33D_{bf} A_b k_{fr} L_R$ kNm

where

D_{bf} = the longitudinal distribution factor, *see Table 4.3.1 Longitudinal distribution factor D bf*

A_b is given in *Vol 1, Pt 5, Ch 4, 3.8 Bow flare impact global loads 3.8.3*

k_{fr} is given in *Vol 1, Pt 5, Ch 4, 3.8 Bow flare impact global loads 3.8.1*

L_R is given in *Vol 1, Pt 5, Ch 4, 1.2 Definitions and symbols 1.2.1*

It is not required to consider a hogging bow flare impact bending moment.

3.8.5 If the bow flare impact bending moment, M_{BF}, is greater than the wave bending moment, M_W, *see Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments 3.3.1*, at any position along the length then M_W is to be replaced by M_{BF} at these positions.

Table 4.3.1 Longitudinal distribution factor D_{bf}

Position	Longitudinal distribution factor D_{bf}
$0{,}0L_R$	0,00
$0{,}4L_R$	1,00
$0{,}5L_R$	1,00
$0{,}6L_R$	0,98

$0,7L_R$	0,95
$0,8L_R$	0,81
$0,9L_R$	0,44
$1,0L_R$	0,00
Note 1. Intermediate values to be obtained by interpolation.	
Note 2. L_R as defined in *Vol 1, Pt 5, Ch 4, 1.2 Definitions and symbols 1.2.1*.	

3.8.6 The bow flare impact shear force, Q_{BF}, associated with the bow flare bending moment is to be taken as follows over the forward half length of the ship:

$$Q_{BF} = 132K_{bf} A_b k_{fr} \text{ kN}$$

where K_{bf} is to be taken as follows:

Positive shear force

K_{bf} = 0,0 aft of $0,5L_R$

= 0,7 between $0,5L_R$ and $0,6L_R$

= 1,0 between $0,7L_R$ and $0,85L_R$

= 0,0 at forward end of L_R

Intermediate values are to be determined by linear interpolation.

Negative shear force

K_{bf} = 0,0 for the length of the ship, L_R

where

A_b = is given in *Vol 1, Pt 5, Ch 4, 3.8 Bow flare impact global loads 3.8.3*

k_{fr} = is given in *Vol 1, Pt 5, Ch 4, 3.8 Bow flare impact global loads 3.8.1*.

3.8.7 If the bow flare impact shear force, Q_{BF}, is greater than the wave shear force, *see Vol 1, Pt 5, Ch 4, 3.4 Vertical wave shear forces*, at any position along the length then the wave shear force, Q_W, is to be taken as Q_{BF} at these positions.

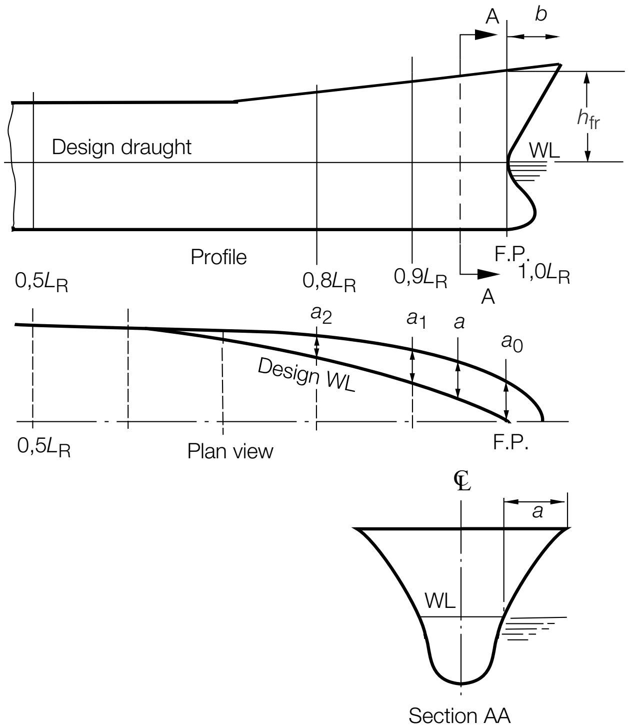


Figure 4.3.3 Derivation of bow shape

3.9 Dynamic bending moments and associated shear forces

3.9.1 The requirements of this section are applicable to mono-hull ships when operating in the planing regime.

3.9.2 This section gives formulae for the derivation of the high frequency dynamic bending moment, shear forces and associated pressures. The bending moment and shear force values are to be used for the global design loads if they are greater than the values derived in accordance with *Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments* and *Vol 1, Pt 5, Ch 4, 3.4 Vertical wave shear forces*

3.9.3 The dynamic bending moment, due to a high speed planning craft landing on a wave crest amidships, at any position along the ship, is to be calculated using the following expression:

$M_{DW} = F_{df} D_{df} D_{df}|M_d|$ kN/m

where

$|M_D| = 51\Delta L_R (16a_{op} - 4a_{bp} - 17a_{sp} - 5) \times 10^{-3}$ kN/m

F_{df} = –1,0 for sagging (negative) moment
= 1,0 for hogging (positive) moment

D_{df} = 0 at aft end of LR
= 1,0 between 0,4L_R and 0,65L_R
= 0 at forward end of L_R

Intermediate values of D_f are to be determined by linear interpolation

a_{op} = vertical acceleration at the LCG, in terms of g, as defined in *Vol 1, Pt 5, Ch 3, 2.4 Design vertical acceleration for ships in the planing regime*

where

a_{bp} = vertical acceleration at forward end of L_R, in terms of g, *Vol 1, Pt 5, Ch 3, 2.4 Design vertical acceleration for ships in the planing regime*

a_{sp} = vertical acceleration at aft end of L_R, in terms of g, *Vol 1, Pt 5, Ch 3, 2.4 Design vertical acceleration for ships in the planing regime*

3.9.4 The non-dimensional vertical acceleration at the LCG, a_{op}, as defined in *Vol 1, Pt 5, Ch 3, 2.4 Design vertical acceleration for ships in the planing regime*, is not to be taken less than 1,0 for the purpose of determining the dynamic bending moment M_{DW}. If the values of a_{bp} and a_{sp} are unknown, the distributions given in *Vol 1, Pt 5, Ch 3, 2.4 Design vertical acceleration for ships in the planing regime* are to be applied.

3.9.5 Bottom longitudinals within 0,4L_R of amidships are subjected to the following effective pressure, P_{ds}:

$$P_{ds} = 0{,}14 P_{dl} + 8T \text{ kN/m}^2$$

where

= P_{dl} is as defined in *Vol 1, Pt 5, Ch 3, 4.5 Bottom impact pressure for ships operating in the planing regime*

T is defined in 1.2.1.

3.9.6 Bottom plating within 0,4L_R of amidships is subjected to the following effective pressure, P_{dp}:

$$P_{dp} = 0{,}175 P_{dl} + 10\text{T kN/m}^2$$

3.9.7 The dynamic shear force, Q_{DW}, at any position along the ship is given by:

$$Q_{DW} = 4K_f M_D / L_R \text{ kN}$$

where

= M_D is defined in *Vol 1, Pt 5, Ch 4, 3.9 Dynamic bending moments and associated shear forces 3.9.3*

= K_f is defined in *Vol 1, Pt 5, Ch 4, 3.4 Vertical wave shear forces 3.4.1*

3.10 Hull girder design loads

3.10.1 The Rule bending moment envelope, M_R, and associated shear force envelope, Q_R, for use with the scantling determination procedures in *Vol 1, Pt 6, Ch 3 Scantling Determination* are to be determined as follows:

(a) The Rule vertical bending moment envelope, M_R, is to be taken as ($M_W + M_S$), as defined in *Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments* and *Vol 1, Pt 5, Ch 4, 2.2 Still water bending moments*, taking into account the hogging and sagging conditions.

(b) The Rule vertical shear force envelope, Q_R, is to be taken as ($Q_W + Q_S$), as defined in *Vol 1, Pt 5, Ch 4, 3.4 Vertical wave shear forces* and *Vol 1, Pt 5, Ch 4, 2.3 Still water shear forces*, taking into account the hogging and sagging conditions.

3.10.2 The values M_W and Q_W are to be replaced by M_{BF} and Q_{BF} if these are larger, *see Vol 1, Pt 5, Ch 4, 3.4 Vertical wave shear forces* and *Vol 1, Pt 5, Ch 4, 3.8 Bow flare impact global loads 3.8.7* Similarly, the Values M_W and Q_W are to be replaced by M_{DW} and Q_{DW} if these are larger.

■ *Section 4*
Extreme hull girder loads

4.1 Introduction

4.1.1 The extreme hull girder loads specified in this section are applicable to all mono-hull naval ships for which the optional **ESA1** or **ESA2**, Extreme Strength Assessment, notation is required. The design criteria detailed in this section are to be used in

conjunction with the extreme hull girder strength assessment procedure given in *Vol 1, Pt 6, Ch 4, 3 Extreme Strength Assessment, ESA*

4.1.2 The extreme hull girder loads are typical lifetime maximum values that a ship is likely to encounter if it was to be present in an extreme sea state in sea areas associated with its service area notation.

4.2 Environmental conditions

4.2.1 The environmental design criteria for extreme design analysis given in Chapter 2 are to be used to determine the extreme hull girder loads.

4.2.2 The hull girder loads for the extreme hull girder strength assessment for unrestricted service operation, i.e. service area notation **SA1**, are typical maximum loads that are predicted for extreme winter North Atlantic conditions in head seas at low forward speed.

4.2.3 For other service area notations, the hull girder loads for the extreme hull girder strength assessment are typical maximum loads that are likely to be encountered within the restricted operational area.

4.3 Extreme vertical wave bending moments

4.3.1 For all mono-hull ships, the extreme vertical wave bending moment, M_{WEX}, at any position along the ship is given by:

$$M_{\text{WEX}} = K_{\text{fEX}} M_{\text{W}} \text{ kN m}$$

where

= M_{W} is given in *Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments*

K_{fEX} = extreme scaling factor

= 1,5.

4.3.2 Alternatively the extreme hull girder strength assessment wave loads may be derived using direct calculation methods, model tests or similar taking into account the likely range of wave periods and the environmental conditions specified in *Vol 1, Pt 5, Ch 2 Environmental Conditions*

4.3.3 In deriving the wave loads, the longitudinal distribution of the vertical wave bending moment is to taken in accordance with the longitudinal distribution factor, D_{f}, *see Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments 3.3.1* Where appropriate, the hogging and sagging correction factor, F_{fH} and F_{fS} given in *Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments 3.3.1*, may be used to derive the hogging and sagging bending moments from a direct calculation.

4.3.4 If specified by the Owner, the extreme hogging and sagging vertical wave bending moment or extreme scaling factor, K_{fEX}, may be derived from long-term 'in-service' measurements from a series of ships with similar hull forms, mass distributions and areas of operation.

4.4 Extreme vertical wave shear forces

4.4.1 The extreme vertical wave shear force, Q_{WEX}, at any position along the ship is given by:

$$Q_{\text{WEX}} = K_{\text{fEX}} Q_{\text{W}} \text{ kN}$$

where

Q_{W} = is given in *Vol 1, Pt 5, Ch 4, 3.4 Vertical wave shear forces*

K_{fEX} = the extreme scaling factor, *see Vol 1, Pt 5, Ch 4, 4.3 Extreme vertical wave bending moments*.

4.4.2 Alternatively the method of derivation of the extreme wave shear force may be consistent with that used to derive the bending moments.

4.5 Direct calculation procedures

4.5.1 Direct calculation procedures may be used to derive the extreme hull girder loads. LR's calculation method of the extreme hull girder loads involves derivation of the short term maximum probable responses.

4.5.2 The extreme hull girder loads, M_{WEX} and Q_{WEX}, are to be based on the probable maximum values that are likely to be experienced during severe storms. The parameters of the severe sea state, i.e. significant wave height, wave period range and duration of storm, are given in *Vol 1, Pt 5, Ch 2 Environmental Conditions*.

4.6 Still water shear forces and bending moments

4.6.1 The still water hogging and sagging shear force and bending moment distributions for the extreme hull girder strength assessment are to be taken as the Q_S and M_S distributions defined in *Vol 1, Pt 5, Ch 4, 2.3 Still water shear forces* and *Vol 1, Pt 5, Ch 4, 2.2 Still water bending moments* respectively.

4.7 Extreme hull girder design loads

4.7.1 The extreme hull girder strength design bending moment, M_{REX}, and associated shear forces, Q_{REX}, for all naval ships are to be determined as follows:

(a) The extreme hull girder strength design bending moment, M_{REX}, is to be taken as (M_{WEX} + M_S), as defined in *Vol 1, Pt 5, Ch 4, 4.3 Extreme vertical wave bending moments* and *Vol 1, Pt 5, Ch 4, 4.6 Still water shear forces and bending moments*, taking into account the appropriate hogging and sagging conditions.

(b) The extreme hull girder strength design shear force, Q_{REX}, is to be taken as (Q_{WEX} + Q_S), as defined in *Vol 1, Pt 5, Ch 4, 4.4 Extreme vertical wave shear forces* and *Vol 1, Pt 5, Ch 4, 4.6 Still water shear forces and bending moments*, taking into account the appropriate hogging and sagging conditions.

4.7.2 It is unnecessary to consider the effects of operating at high speed on the extreme design values for extreme hull girder strength. The requirements for bow flare impact global loads may be ignored in the derivation of M_{WEX} and Q_{WEX}.

■ *Section 5*
Residual strength hull girder loads

5.1 Introduction

5.1.1 The residual strength hull girder loads specified in this section are applicable to all displacement mono-hull naval ships for which the optional **RSA1, RSA2** or **RSA3**, Residual Strength Assessment, notation is required. The design criteria detailed in this Section are to be used in conjunction with the residual strength assessment procedure given in *Vol 1, Pt 6, Ch 4, 4 Residual Strength Assessment, RSA*.

5.1.2 The residual strength hull girder loads are used to assess the capability of the ship's global hull girder after suffering structural damage to meet specified global strength requirements. The effects of flooding, as a consequence of structural damage, on the static global bending moments and shear forces are also to be considered.

5.2 Environmental conditions

5.2.1 The environmental design criteria for residual strength analysis given in *Vol 1, Pt 5, Ch 2, 3 Air environment* are to be used to determine the residual strength hull girder loads.

5.2.2 The global loads for the residual strength hull girder strength assessment for unrestricted service operation, i.e. service area notation **SA1**, are typical maximum loads that are predicted in North Atlantic sea conditions that have a probability of exceedance of 20 per cent. The loads predicted for the ship in head seas at low forward speed are to be considered.

5.2.3 For other service area notations, the global loads for the hull girder residual strength assessment are typical maximum loads that are likely to be encountered within the restricted operational area in sea conditions that have a 20 per cent probability of being exceeded.

5.2.4 The designer/builder may stipulate the environmental conditions to be applied to the residual strength assessment. In which case the residual strength notation will be assessed against the required performance level.

5.2.5 The residual strength area reduction factor, K_{fRS}, is given by the following:

$$K_{fRS} = 1{,}1 H_{rw} L_R^{-0{,}48}$$

where

H_{rw} is given in *Vol 1, Pt 5, Ch 2, 2.3 Wave environment 2.3.5*.

5.3 Residual strength vertical wave bending moments

5.3.1 The residual strength wave loads may be derived from the formula given below. The residual strength vertical bending moment specified here is applicable to all mono-hull ships.

5.3.2 The residual strength vertical wave bending moment, M_{WRS}, at any position along the ship is given by:

$$M_{WRS} = K_{fRS} M_W \text{ kN m}$$

where

M_W = is given in *Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments*

K_{fRS} = Residual strength area reduction factor, *see Vol 1, Pt 5, Ch 4, 5.2 Environmental conditions 5.2.5*

5.3.3 Alternatively the residual strength wave loads may be derived using direct calculation methods, model tests or similar taking into account the likely range of wave periods and the environmental conditions specified in *Vol 1, Pt 5, Ch 4, 5.2 Environmental conditions*

5.3.4 In deriving the residual strength wave bending moment, the longitudinal distribution is to be taken in accordance with the longitudinal distribution factor, D_f, *see Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments 3.3.1*. Where appropriate, the hogging and sagging correction factors, F_{fH} and F_{fS} may be used to derive the hogging and sagging bending moments from a direct calculation.

5.3.5 For conventional ships, it is not normally necessary to consider the effects of flooded compartments on the wave bending moments and shear forces.

5.3.6 For bottom damage assessment as a result of grounding, the residual strength vertical wave bending moment may be based on a M_W value derived using a service area factor, f_s, for a **SA4** service area notation; provided that the ship will not be required to proceed beyond sheltered water. Similarly for other damage assessments which are restricted to sheltered water environments, provided that there is no requirement for operation outside sheltered water areas.

5.4 Residual strength vertical wave shear forces

5.4.1 The residual strength vertical wave shear force, Q_{WRS}, at any position along the ship is given by:

$$Q_{WRS} = K_{fRS} Q_W \text{ kN}$$

where

Q_W = is given in *Vol 1, Pt 5, Ch 4, 3.4 Vertical wave shear forces*

K_{fRS} = residual strength area reduction factor, *see Vol 1, Pt 5, Ch 4, 5.2 Environmental conditions 5.2.5*

5.4.2 Alternatively the method of derivation of residual strength wave shear forces is to be consistent with that used to derive the bending moments.

5.5 Direct calculation procedures

5.5.1 Direct calculation procedures may be used to derive the residual strength hull girder loads. LR's calculation method of the residual strength hull girder loads involves derivation of the short term maximum probable responses.

5.5.2 The residual strength hull girder loads are to be based on the probable maximum values that are likely to be experienced during moderately severe sea conditions. The parameters of the seastate, i.e. significant wave height, wave period range and duration of storm, are given in *Vol 1, Pt 5, Ch 2 Environmental Conditions*.

5.6 Damaged still water shear forces and bending moments

5.6.1 The still water hogging and sagging shear force, Q_{SRS}, and bending moment, M_{SRS}, distributions in the damaged condition are to be calculated taking into account any flooding of the ship as a consequence of damage. If no flooding occurs then

the still water values are to be taken from *Vol 1, Pt 5, Ch 4, 2.3 Still water shear forces* and *Vol 1, Pt 5, Ch 4, 2.2 Still water bending moments* respectively.

If no flooding occurs

M_{SRS} = M_S kN m

Q_{SRS} = Q_S kN

or if flooding occurs

M_{SRS} = damaged still water bending moment, sagging (negative) and hogging (positive), in kN m

Q_{SRS} = damaged still water shear force, positive and negative, in kN.

5.6.2 The loading conditions used to derive the undamaged still water shear force and bending moment curves are to be used for the assessment of the damaged still water bending moments together with the addition of flood water in damaged compartments.

5.7 Residual strength hull girder design loads

5.7.1 The residual strength design vertical bending moment, M_{RRS}, and associated shear forces, Q_{RRS}, for all naval ships are to be determined as follows:

(a) The residual strength design bending moment, M_{RRS}, is to be taken as (M_{WRS} + M_{SRS}), as defined in *Vol 1, Pt 5, Ch 4, 5.3 Residual strength vertical wave bending moments* and *Vol 1, Pt 5, Ch 4, 5.6 Damaged still water shear forces and bending moments*, taking into account the appropriate hogging and sagging conditions.
(b) The residual strength design shear forces, Q_{RRS}, is to be taken as (Q_{WRS} + Q_{SRS}), as defined in *Vol 1, Pt 5, Ch 4, 5.4 Residual strength vertical wave shear forces* and *Vol 1, Pt 5, Ch 4, 5.6 Damaged still water shear forces and bending moments*, taking into account the appropriate hogging and sagging conditions.

5.7.2 Where it is required that the ship is to be capable of operating at high speed after damage, it may also be necessary to consider the effects of dynamic bending moments and shear forces.

■ *Section 6*
Loading guidance information

6.1 General

6.1.1 Sufficient information is to be supplied to every ship to enable the Commanding Officer or Master to arrange loading and ballasting in such a way as to avoid the creation of unacceptable stresses in the ship's structure.

6.1.2 This information should include any limiting criteria that were applied to the structural design of the ship, e.g. the maximum and minimum still water bending moments, service area notation with details of service area restrictions.

6.1.3 This information is to be provided by means of a Stability Information Book or Loading Manual and in addition, where required, by means of an approved loading instrument.

6.1.4 An Operational manual which contains the ship's assigned operational envelope is to be provided on board, *see Vol 1, Pt 1, Ch 2, 2 Scope of the Rules* and *18, Ch 1, 1 Background*.

6.2 Loading Manuals or Stability Information Books

6.2.1 A Loading Manual is to be supplied to all ships where longitudinal strength calculations have been required, *see Vol 1, Pt 6, Ch 3, 4.2 Hull girder strength* and *Vol 1, Pt 6, Ch 4, 2.1 General*. The Manual is to be submitted for approval in respect of strength aspects. Where both Loading Manual and loading instrument are supplied the Loading Manual must nevertheless be approved from the strength aspect. In this case the Manual is to be endorsed to the effect that any departures from these conditions in service are to be arranged on the basis of the loading instrument and the allowable local loadings shown in the Manual.

6.2.2 The Loading Manual is to be based on the final data of the ship and is to include well-defined lightweight distribution and buoyancy data.

6.2.3 Details of the loading conditions are to be included in the manual as applicable.

6.2.4 The Loading Manual is also to contain the following:

(a) Values of actual and permissible still water bending moments and shear forces and where applicable limitations due to torsional loads.
(b) The allowable local loadings for the structure.
(c) Details of the carriage of any substances where there are constraints imposed by the use of an accepted coating in association with a system of corrosion control.
(d) Where the ship has the capability to significantly alter the draught forward by filling water ballast tanks, then a note saying: 'Scantlings approved for minimum draught forward of...m with ballast tanks No ... filled. In heavy weather conditions the forward draught is not to be less than this value. If, in the opinion of the Commanding Officer or Master, sea conditions are likely to cause regular slamming, then other appropriate measures such as change in speed, heading or an increase in draught forward may also need to be taken.'

6.2.5 Where applicable, the Manual is also to contain the procedure for ballast exchange and sediment removal at sea and the correct use of tanks.

6.2.6 Where alteration to structure, lightweight, cargo distribution or draught is proposed, revised information is to be submitted for approval.

6.3 Loading instrument

6.3.1 In addition to a Loading Manual, an approved loading instrument is to be provided for all ships where LR is greater than 65 m except as noted below. The following ships are exempt from this requirement:

(a) ships with very limited possibilities for variations in the distribution of cargo and ballast;
(b) ships with a regular or fixed operational pattern.

6.3.2 The loading instrument is to be capable of calculating shear forces and bending moments, and where necessary cargo torque, in any load or ballast condition at specified readout points and is to indicate the permissible values. The instrument is to be certified in accordance with LR procedures for the approval of longitudinal strength and stability calculation programs.

6.3.3 The instrument readout points are usually selected at the position of the transverse bulkheads or other obvious boundaries. As many readout points as considered necessary by LR are to be included, e.g. between bulkheads.

6.3.4 Where the ship has the capability to significantly alter the draught forward by filling water ballast tanks, then a notice is to be displayed on the loading instrument stating: 'Scantlings approved for minimum draught forward of... m with ballast tanks No ... filled. In heavy weather conditions the forward draught is not be to less than this value. If, in the opinion of the Commanding Officer or Master, sea conditions are likely to cause regular slamming, then other appropriate measures such as change in speed, heading or an increase in draught forward may also need to be taken.'

6.3.5 Where alterations to structure are carried out which result in a change in the lightweight or deadweight distribution, the loading instrument is to be modified accordingly and details submitted for approval.

6.3.6 The operation of the loading instrument is to be verified by the Surveyor upon installation and at Annual and Periodical Surveys as required in *Vol 1, Pt 5, Ch 3 Local Design Loads*. An Operation Manual for the instrument is to be verified as being available on board.

6.3.7 Where an onboard computer system having a longitudinal strength or a stability computation capability is provided as an Owner's option, it is recommended that the system be certified in accordance with LR's document entitled Approval of Longitudinal Strength and Stability Calculation Programs.

Section 1
Application

1.1 General

1.1.1 The Rules apply to sea-going monohull ships of normal form, proportions and speed. Although the Rules are, in general, for steel ships of all welded construction, other materials for use in hull construction will be specially considered on the basis of the Rules.

1.1.2 An overview of the structural design process is illustrated in *Figure 1.1.1 Overview of the structural design process*

1.2 Equivalents

1.2.1 Alternative scantlings and arrangements may be accepted as equivalent to the Rule requirements. Details of such proposals are to be submitted for consideration in accordance with *Vol 1, Pt 3, Ch 1, 3 Equivalents*.

1.3 Symbols and definitions

1.3.1 The symbols and definitions for use throughout this Part are as defined within the appropriate Chapters and Sections.

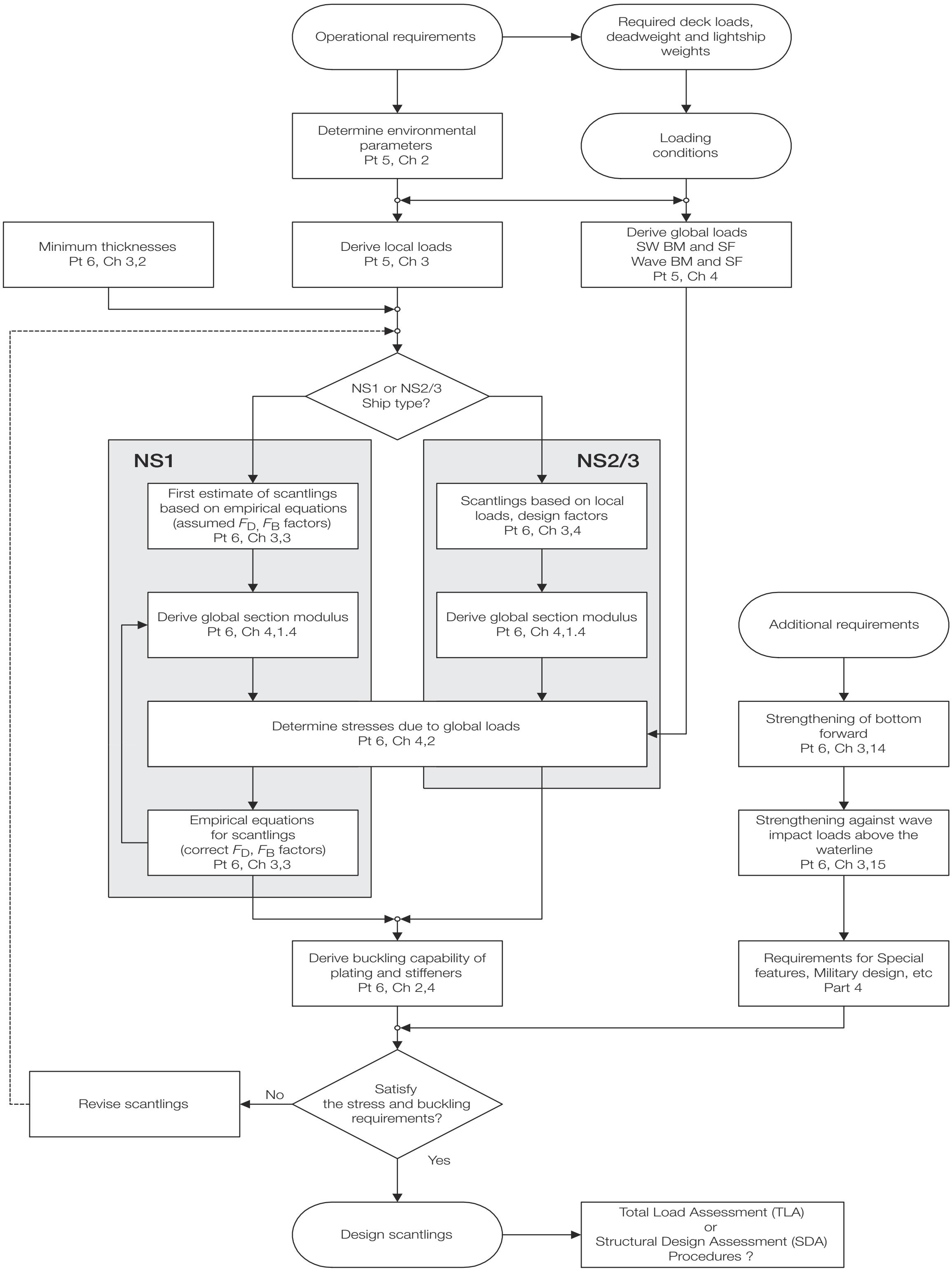


Figure 1.1.1 Overview of the structural design process

Section 2
General requirements

2.1 General

2.1.1 Limitations with regard to the application of these Rules are indicated in the various Chapters for differing ship types.

2.2 Plans to be submitted

2.2.1 Plans are to be of sufficient detail for plan approval purposes. For all areas of structure listed below the submitted plans are to show all plating thickness, stiffeners sizes and spacings, bracket arrangements and connections. Where appropriate, the plans should clearly show the allowance for corrosion margin or enhanced scantlings. Welding, constructional arrangements and tolerances are also to be submitted and this may be in the form of a booklet.

2.2.2 In general all items of steel structure are to be shown except where they are ineffective in supporting hull girder and local loads and do not impinge on such structure.

2.2.3 Equipment seating and supports are to be shown where they require additional stiffening and support to be incorporated in items of hull structure. In such cases the loading on the seating is also to be supplied. Generally total combined equipment weights on seating less than 0,5 tonnes need not be considered.

2.2.4 Normally the plans for each item will be able to be contained on a few sheets. Unit or production drawings will not be accepted.

2.2.5 Plans covering the following items are to be submitted:

- Midship and other critical sections showing longitudinal and transverse material.
- Profile and decks.
- Shell expansion.
- Structural continuity plan showing shadow areas of openings, longitudinally effective material and primary structural continuity material.
- Oiltight and watertight bulkheads.
- Double bottom construction.
- Pillars and girders.
- Aft end construction.
- Engine room construction.
- Engine and thrust seatings.
- Fore end construction.
- Storing routes.
- Deckhouses and superstructures.
- Propeller brackets and appendages.
- Rudder, stock and tiller.
- Equipment.
- Loading Manuals and stability information booklets, preliminary and final (where applicable).
- Scheme of corrosion control (where applicable) including; location of anodes, method of attachment, details of cathodic protection system.
- Ice strengthening.
- Welding schedule.
- Hull penetration plans including scuppers, sea connections, overboard discharges, arrangements and fittings.
- Support structure for masts, derrick posts, cranes, RAS points, weapons handling/stowage or machinery lifting point and large items of equipment.
- Bilge keels showing material grades, welded connections and detail design.
- Flight deck arrangement and structure.

Additionally, for in-water survey the following plans and information are to be submitted:

- Details showing how rudder pintle and bush clearances are to be measured and how the security of the pintles in their sockets are to be verified with the ship afloat.
- Details showing how stern bush clearances are to be measured with the ship afloat.
- Details of high resistant paint, for information only.

2.2.6 The following supporting documents are to be submitted:

- General arrangement.
- Capacity plan.
- Lines plan or equivalent.
- Dry-docking plan.
- Towing and mooring arrangements.
- Corrosion margin policy.

2.2.7 The following supporting calculations are to be submitted:

- Equipment number.
- Hull girder still water and dynamic bending moments and shear forces as applicable.
- Midship section and other critical section modulus.
- Structural items in the aft end, midship and fore end regions of the ship.

2.2.8 In the process of plan approval and from Fatigue Design Assessment and Structural Design Assessment certain critical locations may be identified which require special attention. Plans and records of production are to be submitted in accordance with the construction monitoring procedures associated with the notation **CM**.

2.2.9 Where the specific notations are applied for additional plans will be required.

2.3 Plans to be supplied to the ship

2.3.1 To facilitate the ordering of materials for repairs, plans listed in *Vol 1, Pt 6, Ch 1, 2.2 Plans to be submitted 2.2.5* are to be carried on board the ship. They are to clearly indicate the disposition and grades (other than Grade A) of hull structural steel, the extent and location of higher tensile steel together with details of specification and mechanical properties, and any recommendations for welding, working and treatment of these steels.

2.3.2 Similar information is to be provided where aluminium alloy or other materials are used in the construction.

2.3.3 A copy of the final Loading Manual or Stability Information booklet, when approved, is to be placed on board the ship.

2.3.4 Details of any corrosion control system fitted are to be placed on board the ship.

2.3.5 Approved plans and information covering the items detailed in *Vol 1, Pt 6, Ch 1, 2.2 Plans to be submitted 2.2.5* relating to in-water survey are to be placed on board the ship.

2.4 Novel features

2.4.1 Where the proposed construction of any part of the hull or machinery is of novel design, or involves the use of unusual material, or where experience, in the opinion of LR, has not sufficiently justified the principle or mode of application involved, special tests or examinations before and during service may be required. In such cases a suitable notation may be entered in the *Register Book*.

2.5 Enhanced scantlings

2.5.1 Where scantlings in excess of the approved Rule requirement are fitted at defined locations as corrosion margins or for other purposes, a notation **ES**, 'Enhanced Scantlings', will be assigned and it will be accompanied by a list giving items to which the enhancement has been applied and the increase in scantling. For example, the item 'bottom shell (strakes A, B, C, D)+2' will indicate that an extra 2 mm has been fitted to the bottom shell of the ship for the particular strakes listed, *see also Vol 1, Pt 6, Ch 6, 2.10 Corrosion margin* In addition the plans submitted for approval are to contain the enhanced scantling plan, together with the nominal thickness, less the enhancement adjacent, in brackets.

2.6 Direct calculations

2.6.1 Direct calculations may be specifically required by the Rules and may be required for ships having novel design features or in support of alternative arrangements and scantlings. LR may, when requested, undertake calculations on behalf of designers and make recommendations with regard to suitability of any required model tests.

2.7 Exceptions

2.7.1 Ships of unusual form, proportions or speed, with unusual features, or for special or restricted service, not covered specifically by the Rules, will receive individual consideration based on the general requirements of the Rules.

Section 1
General

1.1 General

1.1.1 The guidance notes, information and formulae contained within this chapter are to be used in the scantling determination (*Vol 1, Pt 6, Ch 3 Scantling Determination*) and total load assessment.

1.2 Equivalents

1.2.1 Lloyd's Register (hereinafter referred to as 'LR') will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by Rule requirements in accordance with *Vol 1, Pt 3, Ch 1, 3 Equivalents*

1.3 Symbols and definitions

1.3.1 The symbols used in this Chapter are defined below and in the appropriate Section:

Z = section modulus of stiffening member, in cm^3

I = moment of inertia, in cm^4

A_w = shear area of stiffener web, in cm^2

l = overall length of stiffener or primary member, in metres

l_e = effective span length, in metres, as defined in *Vol 1, Pt 6, Ch 2, 2.6 Determination of span length*

p = design pressure, in kN/m^2

s = secondary stiffener spacing, in mm

S = primary stiffener spacing, in metres

t_p = plating thickness, in mm

β = panel aspect ratio correction factor as defined in *Vol 1, Pt 6, Ch 2, 2.5 Aspect ratio correction*

γ = convex curvature correction factor as defined in *Vol 1, Pt 6, Ch 2, 2.4 Convex curvature correction*

k_s = higher tensile steel factor for local loads, *see Vol 1, Pt 6, Ch 5, 2.1 Design criteria 2.1.1*

k_L = higher tensile steel factor for global loads, *see Vol 1, Pt 6, Ch 5, 2.1 Design criteria 2.1.2*

σ_o = guaranteed minimum yield strength of the material, in N/mm^2

τ_o = shear strength of the material in N/mm^2

$= \dfrac{\sigma_{o}}{\sqrt{3}}$

E = modulus of elasticity, in N/mm^2.

1.4 Rounding policy for Rule plating thickness

1.4.1 Where plating thicknesses as determined by the Rules require to be rounded then this should be carried out to the nearest full or half millimetre, with thicknesses 0,75 and 0,25 being rounded up.

1.5 Material properties

1.5.1 The basic grade of steel used in the determination of the Rule scantling requirements is taken as mild steel with the following mechanical properties:

(a) Yield strength (minimum) σ_o = 235 N/mm^2
(b) Tensile strength = 400–490 N/mm^2
(c) Modulus of elasticity, E = 200 x 10^3 N/mm^2.

1.6 Higher tensile steel

1.6.1 Steels having a yield stress not less than 265 N/mm^2 are regarded as higher tensile steels.

1.6.2 Where higher tensile steels are to be used, due allowance is given in the determination of the Rule requirement for plating thickness, stiffener section modulus, inertia and cross-sectional area by the use of higher tensile steel correction factors k_s and k_L or f_{hts}. Normally, this allowance is included in the appropriate scantling requirements. Where this is not the case, the following correction factors may be applied:

(a) Plating thickness factor = $\sqrt{k_S}$ for local loads

= $\sqrt{k_L}$ for global loads

(b) Section modulus and cross sectional area factor = k_s

where k_s and k_L are defined in *Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*

f_{hts} is defined in *Vol 1, Pt 6, Ch 5, 1.3 Higher tensile steel*

1.6.3 Higher tensile steel may be used for both deck and bottom structures or deck structure only. Where fitted for global strength purposes, it is to be used for the whole of the longitudinal continuous material for the following vertical distances:

(a) z_{htd} below the line of deck at side

$$Z_{htd} = \left(1 - \frac{k_L}{F_D}\right) z_D \text{ m}$$

(b) z_{htb} above the top of keel

$$Z_{htb} = \left(1 - \frac{k_L}{F_B}\right) z_B \text{ m}$$

In the above formulae F_D and F_B are to be taken not less than k_L

where

(a) F_D and F_B are defined in Ch 3,3.6. Note the F_D and F_B factors derived in*Vol 1, Pt 6, Ch 3, 3.6 Local reduction factors* for NS1 ships may also be applied to ship types NS2 and NS3.
(b) z_D and z_B are the vertical distances, in m, from the transverse neutral axis of the hull cross-section to the uppermost continuous longitudinally effective material and to the top of the keel respectively.

k_L is defined in *Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*.

1.6.4 The designer should note that there is no increase in fatigue performance with the use of higher tensile steels.

Section 2
Structural design

2.1 General

2.1.1 This Section gives the basic principles to be adopted in determining the Rule structural requirements given in *Vol 1, Pt 6, Ch 3 Scantling Determination*

2.1.2 For derivation of scantlings of stiffeners, beams, girders, etc. the formulae in the Rules are normally based on elastic or plastic theory using simple beam models supported at one or more points and with varying degrees of fixity at the ends, associated with an appropriate concentrated or distributed load.

2.1.3 The stiffener, beam or girder strength is defined by a section modulus and moments of inertia requirements. In addition there are local requirements for web thickness or flange thickness.

2.1.4 Some of the details given in this section will be specially considered for ships with a military distinction notation **MD**.

2.2 Effective width of attached plating, b_e

2.2.1 The effective geometric properties of rolled or built sections are to be calculated directly from the dimensions of the section and associated effective area of attached plating. Where the web of the section is not normal to the actual plating, and the angle exceeds 20°, the properties of the section are to be determined about an axis parallel to the attached plating.

2.2.2 For stiffening members, the geometric properties of rolled or built sections are to be calculated in association with an effective area of attached load bearing plating of thickness t_p, in mm, and a breadth b_e, in mm.

2.2.3 The effective breadth of attached plating to secondary stiffener members b_e, is to be taken as:

$$b_e = 40t_p \text{ mm}$$

or 600 mm, whichever is the greater

or the actual spacing of stiffeners in mm, whichever is the lesser.

2.2.4 The effective breadth of attached plating to primary support members (girders, transverses, webs, etc.), b_e, is to be taken as:

$$b_e = 300S\left(\frac{l}{S}\right)^{2[\text{solm}\,0]3} \text{mm but is not to exceed } 1000S$$

where

S and l are as defined in *Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*

2.3 Section properties

2.3.1 The dimensions of rolled and built stiffeners are illustrated in *Figure 2.2.1 Dimensions of longitudinals* The section properties of stiffeners can be based on the illustrated dimensions if manufacturer's information is not available.

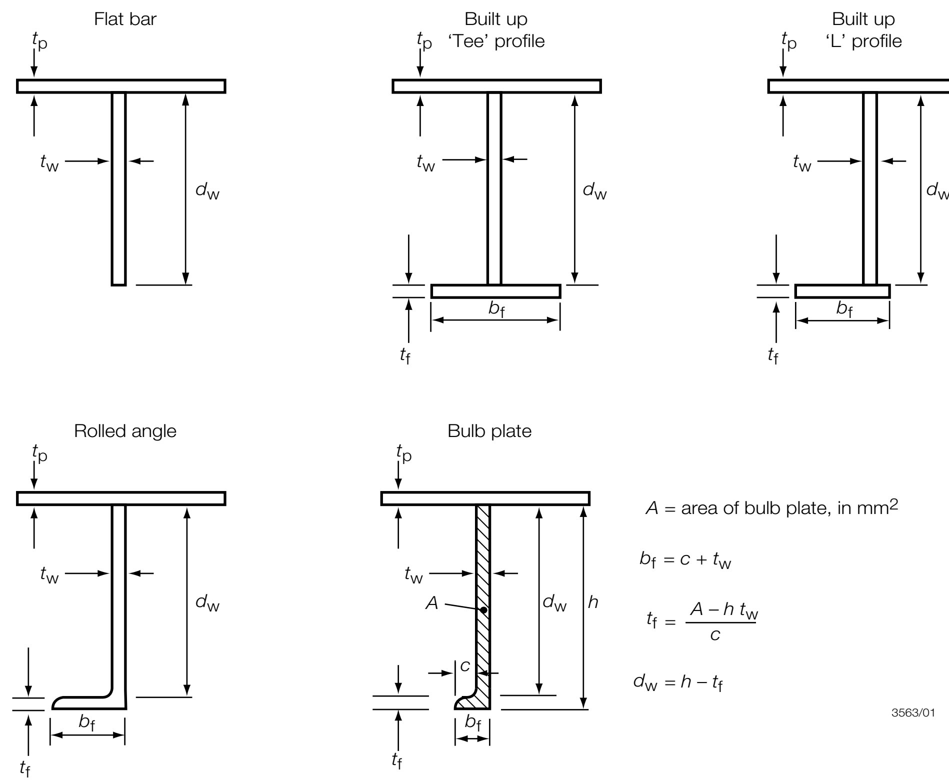


Figure 2.2.1 Dimensions of longitudinals

2.3.2 The effective section properties of a corrugation over a spacing b, *see Figure 2.2.2 Corrugated section*, is to be calculated from the dimensions and, for symmetrical corrugations, may be taken as:

Section modulus

$$Z = \frac{\mathrm{d_w}}{6000}\left(3\mathrm{b_e t_p} + \mathrm{ct_w}\right)\mathrm{cm}^3$$

Moment of inertia

$$I = \frac{\mathrm{Z}}{10}\left(\frac{\mathrm{d_w}}{2}\right)\mathrm{cm}^4$$

Shear area

$$A_\mathrm{w} = \frac{\mathrm{d_w t_w}}{100}\mathrm{cm}^2$$

where

d_w, b_f, t_p, c and t_w are measured, in mm, and are as shown in *Figure 2.2.2 Corrugated section*. The value of b_e is to be taken not greater than b_f or:

$50t_p\sqrt{k_s}$ for welded corrugations

$60t_P\sqrt{k_s}$ for cold formed corrugations

k_s = local high strength steel factor, *see Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*

The value of θ is to be not less than 40°.

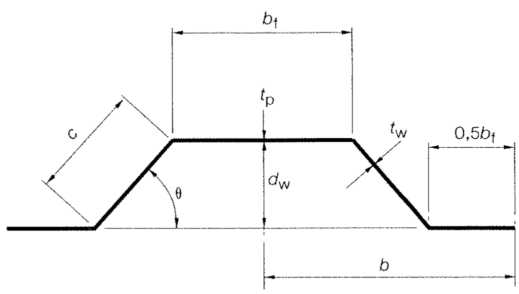


Figure 2.2.2 Corrugated section

2.3.3 The section properties of a double skin primary member over a spacing b, *see Figure 2.2.3 Double skin section*, may be calculated as:

Section modulus

$$Z = \frac{d_w}{6000}\left(6\,f\,b\,t_p + d_w t_w\right)\text{cm}^3$$

Moment of inertia

$$I = \frac{Z}{10}\left(\frac{d_w}{2}\right)\text{cm}^4$$

Shear area

$$A_w = \frac{d_w t_w}{100}\text{cm}^2$$

where

d_w, b, t_p and t_w are measured, in mm, and are as shown in *Figure 2.2.2 Corrugated section*

$$f = 0,3\left(\frac{1000l}{b}\right)^{2/3}\text{ mm but is not to exceed 1,0}$$

NOTE

If the plate flanges of the double bulkhead are of unequal thicknesses, then the equations in *Vol 1, Pt 6, Ch 2, 2.3 Section properties 2.3.4* may be used with $b_e = b_f = f\,b$.

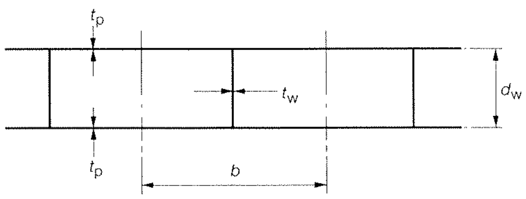


Figure 2.2.3 Double skin section

2.3.4 The effective section properties of a built section, *see Vol 1, Pt 6, Ch 2, 2.2 Effective width of attached plating, be 2.2.1*, may be taken as:

Section modulus of flange

$$Z_f = \frac{A_f d_w}{10} + \frac{A_w d_w}{60}\left(1 + \frac{2(A_p - A_f)}{2A_p + A_w}\right) cm^3$$

Neutral axis of section above plating

$$x_{na} = \frac{d_w}{A}\left(\frac{A_w}{2} + A_f\right) mm$$

Moment of inertia about neutral axis

$$I = \frac{z_f}{10}\left(d_w - x_{na}\right) cm^4$$

Section modulus at plate

$$Z_p = 10\frac{I}{X_{na}} cm^3$$

Shear area

$$A_w = \frac{d_w t_w}{100} cm^2$$

where

A_f = area of face plate of flange in cm^2

A_w = area of web plating in cm^2

A_p = area of attached plating in cm^2, *see* 2.3.5

A = $A_f + A_w + A_p$

d_w = the depth, in mm, of the web between the inside of the face plate and the attached plating. Where the member is at right angles to a line of corrugations, the minimum depth is to be taken

b_e = effective breadth of attached plating, in mm, *see Vol 1, Pt 6, Ch 2, 2.2 Effective width of attached plating, be*

b_f, t_f, d_w, t_w and t_p are in mm and are illustrated in *Figure 2.2.1 Dimensions of longitudinals*.

2.3.5 The geometric properties of primary support members (i.e. girders, transverses, webs, stringers, etc.) attached to corrugated bulkheads, are to be calculated in association with an effective area of attached load bearing plating, A_p, determined as follows:

(a) For a member attached to corrugated plating and parallel to the corrugations:

$A_p = b_f t_p/100$ cm^2

(*See Figure 2.2.2 Corrugated section*).

(b) For a member attached to corrugated plating and at right angles to the corrugations:

A_p is to be taken as equivalent to the area of the face plate of the member.

2.4 Convex curvature correction

2.4.1 The thickness of plating as determined by the Rules may be reduced where significant curvature exists between the supporting members. In such cases a plate curvature correction factor may be applied:

γ = plate curvature factor

= $1 - d_c/s_c$, and is not to be taken as less than 0,7

d_c = the distance, in mm, measured perpendicularly from the chord length, s_c, (i.e. spacing in mm) to the highest point of the curved plating arc between the two supports, *see Figure 2.2.4 Convex curvature*

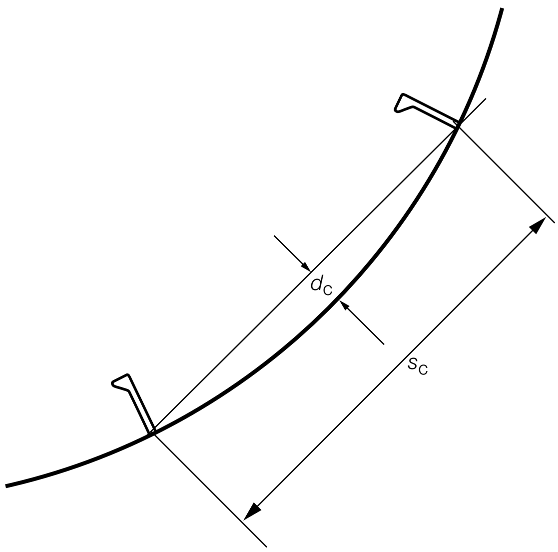


Figure 2.2.4 Convex curvature

2.5 Aspect ratio correction

2.5.1 The thickness of plating as determined by the Rules may be reduced when the panel aspect ratio is taken into consideration. In such cases a panel aspect ratio correction factor may be applied:

β = aspect ratio correction factor

= $A_R (1 - 0{,}25 A_R)$ for $A_R \leq 2$

= 1 for $A_R > 2$

A_R = panel aspect ratio

= panel length/panel breadth.

2.6 Determination of span length

2.6.1 The effective span length, l_e, of a stiffening member is generally less than the overall length, l, by an amount which depends on the design of the end connections. The span points, between which the value of l_e is measured, are to be determined as follows:

(a) For rolled or built-up secondary stiffening members:

The span point is to be taken at the point where the depth of the end bracket, measured from the face of the secondary stiffening member, is equal to the depth of the member, *see Figure 2.2.5 Definition of span points*. Where there is no end bracket, the span point is to be measured between primary member webs.

(b) For primary support members:

The span point is to be taken at a point distant, b_s, from the end of the member

$$b_s = b_b\left(1 - \frac{d_w}{d_b}\right)$$

where b_s, b_b, d_w and d_s are as shown in *Figure 2.2.5 Definition of span points*

2.6.2 Where the stiffening member is inclined to a vertical or horizontal axis and the inclination exceeds 10°, the span is to be measured along the member.

2.6.3 Where the stiffening member is curved then the span is to be taken as the effective chord length between span points.

2.6.4 It is assumed that the ends of stiffening members are substantially fixed against rotation and displacement. If the arrangement of supporting structure is such that this condition is not achieved, consideration will be given to the effective span to be used for the stiffener.

2.7 Plating general

2.7.1 The equation given in this sub Section is to be used to determine the thickness of plating for NS2 and NS3 ship types. The design pressure, *p*, is given in the Tables in *Vol 1, Pt 6, Ch 3, 4 NS2 and NS3 scantling determination* for each structural component and is to be used with the limiting stress coefficient, *see Vol 1, Pt 6, Ch 5, 3.1 Design criteria 3.1.1*, to determine the required plate thickness.

2.7.2 The requirements for the thickness of plating, $t_{\rm p}$, is, in general, to be in accordance with the following:

$$t_{\rm p} = 22{,}4\, s\ \gamma\ \beta \sqrt{\frac{p}{f_{\sigma}\,\sigma_{\rm o}}} \times 10^{-3} \text{mm}$$

where

p = is the design pressure, in kN/m^2, given in *Vol 1, Pt 6, Ch 3, 4 NS2 and NS3 scantling determination*

f_{σ} = limiting stress coefficient for local plate bending for the plating area under consideration given in *Vol 1, Pt 6, Ch 5, 3 Scantling determination for NS2 and NS3 ships* σ_b column in *Table 5.3.2 Allowable stress factors f 1*, *see also Vol 1, Pt 6, Ch 5, 3.1 Design criteria 3.1.1*.

s, γ, β, $\sigma_{\rm o}$ are as defined in *Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*

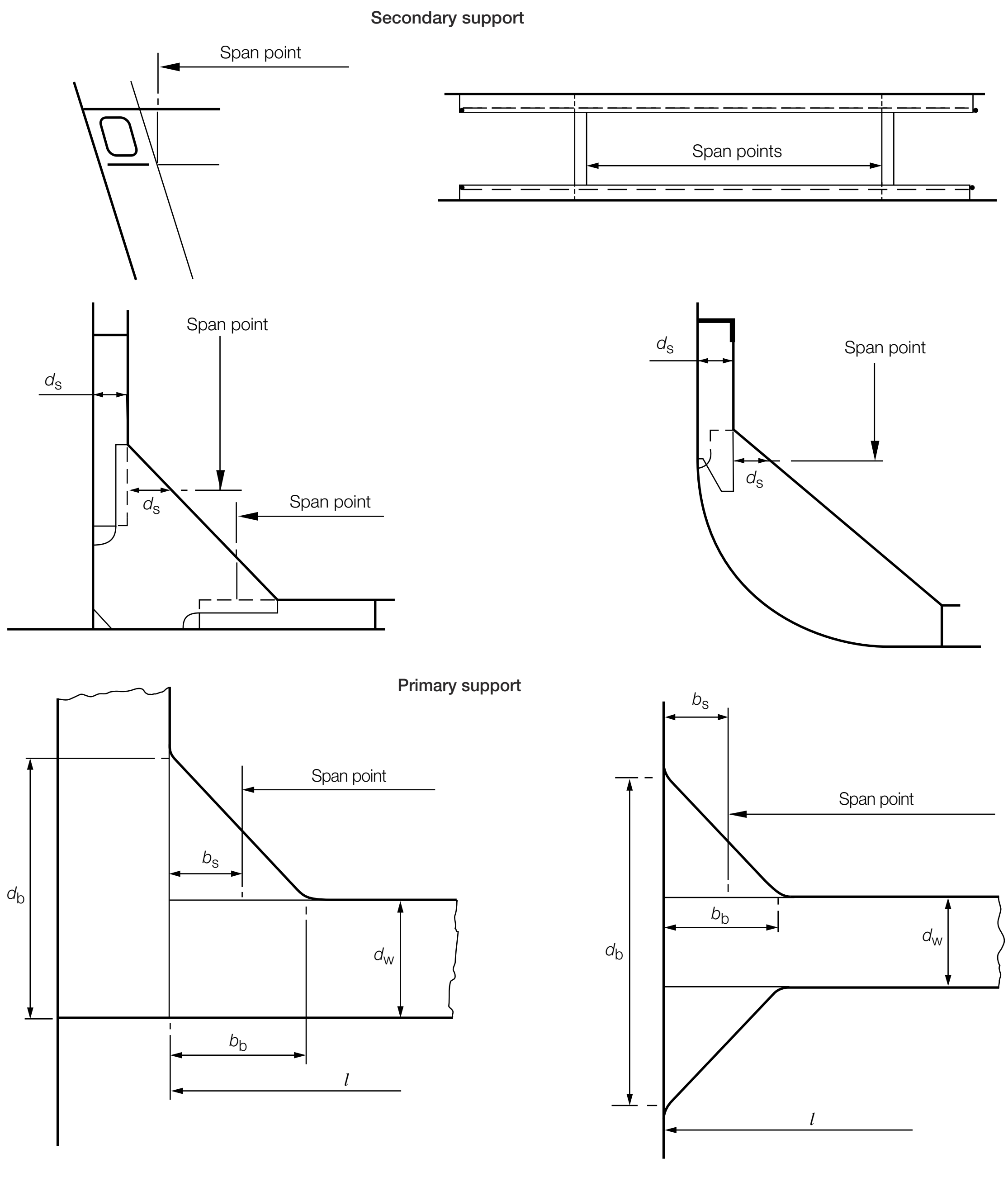


Figure 2.2.5 Definition of span points

2.8 Stiffening general

2.8.1 The equations given in this sub Section are to be used to derive the scantling requirements for stiffeners. The design pressure, p, is given in the Tables in *Vol 1, Pt 6, Ch 3, 4 NS2 and NS3 scantling determination* for each structural component and is to be used with the limiting stress coefficient, *see Vol 1, Pt 6, Ch 5, 3.1 Design criteria 3.1.1* to determine the required section modulus, web area and inertia of the stiffeners.

2.8.2 The requirements for section modulus, inertia and web area of stiffening members subjected to pressure loads are, in general, to be in accordance with the following:

(a) For secondary members:

Section modulus:

$$Z = \frac{\varphi_z p s l_e^2}{f_\sigma \sigma_o} \text{ cm}^3$$

Inertia:

$$I = \frac{100 \varphi_I p s l_e^3}{f_\delta E} \text{ cm}^4$$

Web area:

$$A_w = \frac{\varphi_A p s l_e}{100 f_\tau \tau_o} \text{ cm}^2$$

(b) For primary members:

Section modulus:

$$Z = \frac{10^3 \varphi_z p S l_e^2}{f_\sigma \sigma_o} \text{cm}^3$$

Inertia:

$$I = \frac{10^5 \varphi_I p S l_e^3}{f_\delta E} \text{cm}^4$$

Web area:

$$A_w = \frac{10 \varphi_A p S l_e}{f_\tau \tau_o} \text{cm}^2$$

where

p = is the design pressure, in kN/m^2, given in *Vol 1, Pt 6, Ch 3, 4 NS2 and NS3 scantling determination*

φ_Z = section modulus coefficient dependent on the loading model assumption taken from *Table 2.2.1 Section modulus, inertia and web area coefficients for different load models*

f_σ = limiting local stiffener bending stress coefficient for stiffening member given in *Vol 1, Pt 6, Ch 5, 3.1 Design criteria 3.1.1*

φ_I = inertia coefficient dependent on the loading model assumption taken from *Table 2.2.1 Section modulus, inertia and web area coefficients for different load models*

f_δ = limiting inertia coefficient for stiffener member given in *Vol 1, Pt 6, Ch 5, 3.1 Design criteria 3.1.1*

φ_A = web area coefficient dependent on the loading model assumption taken from *Table 2.2.1 Section modulus, inertia and web area coefficients for different load models*

f_τ = limiting web area coefficient for stiffener member given in *Vol 1, Pt 6, Ch 5, 3.1 Design criteria 3.1.1*

E, S, s, l_e, σ_o and τ_o are as defined in *Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*.

2.8.3 The requirements for section modulus, inertia and web area of stiffening members subjected to point loads are, in general, to be in accordance with the following:

(a) For primary and secondary members:

Section modulus:

$$Z = \frac{10^3 \varphi_z F l_e}{f_\sigma \sigma_o} \text{cm}^3$$

Inertia

$$I = \frac{10^5 \varphi_I F l_e^2}{f_\delta E} \text{cm}^4$$

Web area

$$A_w = \frac{10 \varphi_A F}{f_\tau \tau_o} \text{cm}^2$$

where

F = is the design point load, in kN

Φ_Z = section modulus coefficient dependent on the loading model assumption taken from *Table 2.2.1 Section modulus, inertia and web area coefficients for different load models*

f_σ = limiting local stiffener bending stress coefficient for stiffening member given in *Vol 1, Pt 6, Ch 5, 3.1 Design criteria 3.1.1*, column σ_x in *Table 5.3.2 Allowable stress factors f 1*

Φ_I = inertia coefficient dependent on the loading model assumption taken from *Table 2.2.1 Section modulus, inertia and web area coefficients for different load models*

f_δ = limiting inertia coefficient for stiffener member given in *Vol 1, Pt 6, Ch 5, 3.1 Design criteria 3.1.1*, column f_δ in *Table 5.3.2 Allowable stress factors f 1*

Φ_A = web area coefficient dependent on the loading model assumption taken from *Table 2.2.1 Section modulus, inertia and web area coefficients for different load models*

f_τ = limiting web area coefficient for stiffener member given in *Vol 1, Pt 6, Ch 5, 3.1 Design criteria 3.1.1*, column f_τ in *Table 5.3.2 Allowable stress factors f 1*

E, l_e, and σ_o are as defined in *Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*

2.8.4 Where a stiffener is subjected to a combination of loads, then the requirements are to be based on the linear supposition of those loads onto the stiffener. For example the section modulus requirement for a UDL load and a point load will be as follows:

$$Z = \frac{\varphi_Z p s l_e^2}{f_\sigma \sigma_o} + \frac{10^3 \varphi_z F l_e}{f_\sigma \sigma_o} \text{cm}^3$$

2.9 Proportions of stiffener sections

2.9.1 From structural stability and local buckling considerations, the proportions of stiffening members are, in general, to be in accordance with *Table 2.2.2 Stiffener proportions* For primary member minimum thickness *see Table 6.5.1 Minimum thickness of primary members* in *Vol 1, Pt 6, Ch 6 Material and Welding Requirements*.

2.9.2 Primary members of asymmetrical section are to be supported by tripping brackets at alternate secondary members. If the section is symmetrical, the tripping brackets may be four spaces apart.

2.9.3 Tripping brackets are in general required to be fitted at the toes of end brackets and in way of heavy or concentrated loads such as the heels of pillars.

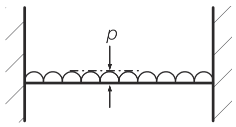
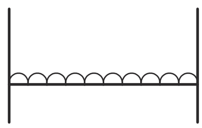
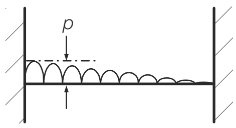
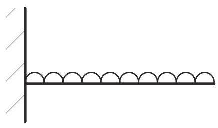
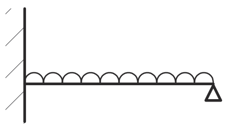
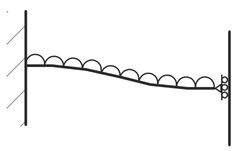
2.9.4 Where the ratio of unsupported width of face plate (or flange) to its thickness exceeds 16:1, the tripping brackets are to be connected to the face plate and on members of symmetrical section, the brackets are to be fitted on both sides of the web.

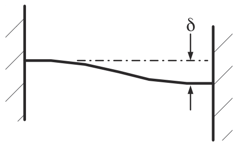
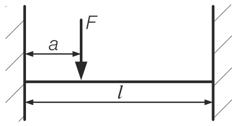
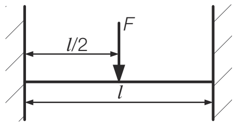
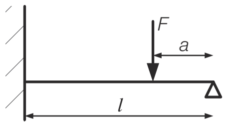
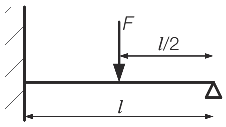
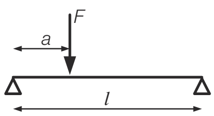
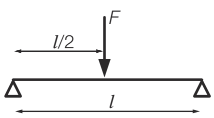
2.9.5 Intermediate secondary members may be welded directly to the web or connected by lugs in accordance with *Vol 1, Pt 6, Ch 6, 5.3 Secondary member end connections*.

2.10 Grillage structures

2.10.1 For complex girder systems, a complete structural analysis using numerical methods may have to be performed to demonstrate that the stress levels are acceptable when subjected to the most severe and realistic combination of loading conditions intended.

Table 2.2.1 Section modulus, inertia and web area coefficients for different load models

Load model	Position (j)			(j)	Web area coefficient Φ_A	Section modulus coefficient Φ_Z	Inertia coefficient Φ_I	Application
	1 end	2 midspan	3 end					
(A)				1 2 3	1/2 – 1/2	1/12 –1/24 1/12	- 1/384 -	Primary and other members where the end fixity is considered encastré Uniformly distributed pressure
(B)				1 2 3	1/2 – 1/2	1/10 –1/10 1/10	- 1/288 -	Local, secondary and other members where the end fixity is considered to be partial Uniformly distributed pressure
(C)				1 2 3	7/20 - 3/20	1/20 – 1/30	- 1/764 -	Linearly varying distributed pressure Built in both ends
(D)				1 2 3	1 - -	1/2 - -	1/8 - -	Uniformly distributed pressure cantilevered beam
(E)				1 2 3	1/2 – 1/2	- 1/8 -	- 5/384 -	Uniformly distributed pressure Simply supported Hatch covers, glazing and other members where the ends are not fixed
(F)				1 2 3	5/8 – 3/8	1/8 –9/128 -	- 1/185 -	Uniformly distributed pressure Cantilever plus simple support
(G)				1 2 3	1 - -	1/3 0 1/3	0 - 1/24	Uniformly distributed pressure Built in one end. Other end free to deflect but slope restrained

(H)		1 2 3	6 - 6	12 - 12	- - -	Built in both ends with forced deflection at one end
(I)		1 2 3	$\frac{(l-a)^2(l+2a)}{l^3}$ – $\frac{a^2(3l-2a)}{l^3}$	$\frac{a(l-a)^2}{l^3}$ $-\frac{2a^2(l-a)^2}{l^4}$ $\frac{a^2(l-a)}{l^3}$	– $\frac{2(l-a)^2a^3}{3(l+2a)^2l^3}$ –	Single point load, load anywhere in the span Built in at both ends
		1 2 3	1/2 - 1/2	1/8 –1/8 1/8	- 1/192 -	Single point load in the centre of the span Built in at both ends
(J)		1 2 3	$\frac{a\left(3l^2-a^2\right)}{2l^3}$ – $\frac{(l-a)^2(2l+a)}{2l^3}$	$\frac{a\left(l^2-a^2\right)}{2l^3}$ $\frac{a(l-a)^2(2l+a)}{2l^4}$ –	– $\frac{a(l-a)^2}{6l^3}\left(\frac{a}{2l+a}\right)^{1/2}$ –	Single point load, load anywhere in the span Cantilever plus simple support
		1 2 3	11/16 - 5/16	3/16 5/32 -	- 1/108 -	Single point load in the centre of the span Cantilever plus simple support
(K)		1 2 3	$\frac{l-a}{l}$ – $\frac{a}{l}$	– $\frac{-a(l-a)}{l^2}$ –	– $\frac{a}{3l^4}\left(\frac{l^2-a^2}{3}\right)^{3/2}$ –	Single point load, load anywhere in the span Simply supported
		1 2 3	1/2 - 1/2	- –1/4 -	- 1/48 -	Single point load in the centre of the span Simply supported

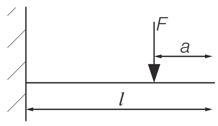
(L)		1	1	$\frac{(l-a)}{l}$	–	Single point load anywhere in the span
		2	–	–	–	
		3	–	–	$\frac{2l^3 - 3l^2 a + a^3}{l^3}$	Cantilevered beam
NOTE In all cases, the coefficient that results in the most pessimistic requirement is to be used in the stiffening equations in *Vol 1, Pt 6, Ch 2, 2.8 Stiffening general*						

Table 2.2.2 Stiffener proportions

Type of stiffener		Requirement		
(1)	Flat bar continuous intercostal	Minimum web thickness:	$t_w = d_w/18$ $t_w = d_w/15$	$\geq$ 2,5 mm $\geq$ 2,5 mm
(2)	Rolled or built sections	(a) Minimum web thickness:	$t_w = d_w/60$	$\geq$ 2,5 mm
		(b) Maximum unsupported face plate (or flange) width:	$b_f = 16t_f$	
Symbols				
t_w = web thickness of stiffener with unstiffened webs, in mm d_w = web depth of stiffener, in mm b_f = face plate (or flange) unsupported width, in mm t_f = face plate (or flange) thickness, in mm				

2.10.2 General or special purpose computer programs or other analytical techniques may be used provided that the effects of bending, shear, axial and torsion are properly accounted for and the theory and idealisation used can be justified.

2.10.3 In general, grillages consisting of slender girders may be idealised as frames based on beam theory provided proper account of the variations of geometric properties is taken. For cases where such an assumption is not applicable, finite element analysis or equivalent methods may have to be used.

■ *Section 3*
Buckling

3.1 General

3.1.1 This Section contains the requirements for buckling control of plate panels subject to in-plane compressive and/or shear stresses and buckling control of primary and secondary stiffening members subject to axial compressive and shear stresses.

3.1.2 The requirement for buckling control of plate panels is contained in *Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements*. The requirements for secondary stiffening members are contained in *Vol 1, Pt 6, Ch 2, 3.7 Secondary stiffening in direction of compression*. The requirements for primary members are contained in *Vol 1, Pt 6, Ch 2, 3.9 Buckling of primary members* and *Vol 1, Pt 6, Ch 2, 3.10 Shear buckling of girder webs*

3.1.3 In general all areas of the structure are to meet the buckling strength requirements for the design stresses. The design stresses are to be taken as the global hull girder bending and shear stresses derived in accordance with *Vol 1, Pt 6, Ch 4 Hull Girder Strength*. In addition, where the structural member is subject to local compressive loads, then the design stresses are to be based on these loads.

3.1.4 The buckling requirements are to be met using the net scantlings, hence any additional thickness for corrosion margin or enhanced scantlings is not included in the scantlings used to assess the buckling performance. For enhanced scantlings, *see Vol 1, Pt 3, Ch 6, 6 Enhanced Scantlings*. For corrosion margins, *see Vol 1, Pt 6, Ch 6, 2.10 Corrosion margin*.

3.2 Symbols

3.2.1 The symbols used in this Section are defined below and in the appropriate sub-Section:

A_R = panel aspect ratio

= $\frac{a}{b}$

a = panel length, i.e. parallel to direction of compressive stress being considered, in mm

b = panel breadth, i.e. perpendicular to direction of compressive stress being considered, in mm

S_p = span of primary members, in metres

σ_e = elastic compressive buckling stress, in N/mm^2

σ_c = critical compressive buckling stress, including the effects of plasticity where appropriate, in N/mm^2

τ_e = elastic shear buckling stress, in N/mm^2

τ_c = critical shear buckling stress, in N/mm^2

b_{eb} = lesser of $1,9 t_p \sqrt{\frac{E}{\sigma_o}}$ or $0,8b$ mm

A_{te} = cross-sectional area of secondary stiffener, in cm^2, including an effective breadth of attached plating, b_{eb}

s = length of shorter edge of plate panel, in mm (typically the spacing of secondary stiffeners)

l = length of longer edge of plate panel, in metres.

S = spacing of primary member, in metres (measured in direction of compression)

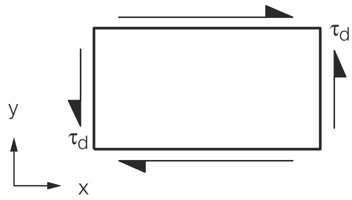
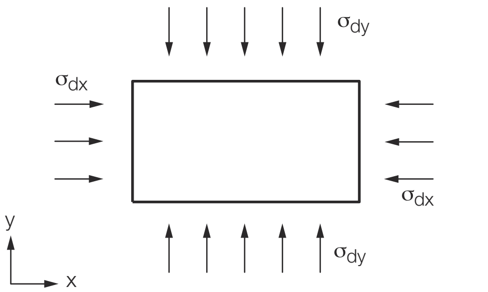
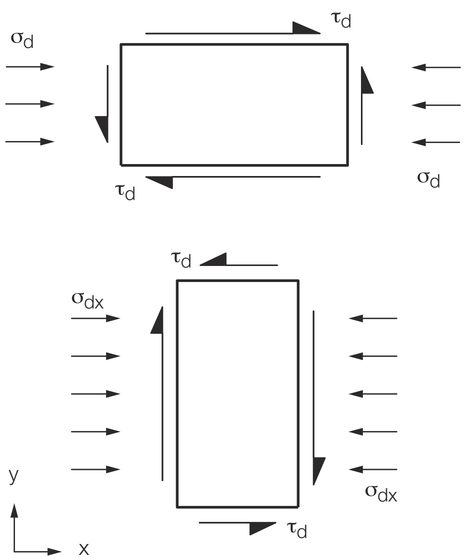
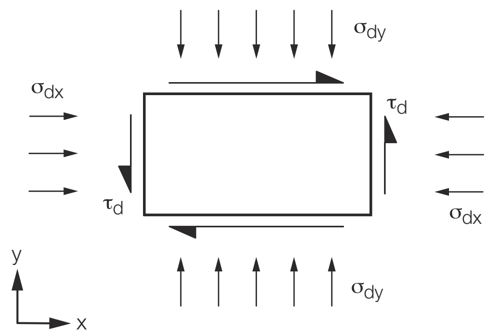
3.3 Plate panel buckling requirements

3.3.1 The section gives methods for evaluating the buckling strength of plate panels subjected to the following load fields:

(a) uni-axial compressive loads;
(b) shear loads;
(c) bi-axial compressive loads;
(d) uni-axial compressive loads and shear loads;
(e) bi-axial compressive loads and shear loads.

3.3.2 The plate panel buckling requirements will be satisfied if the buckling interaction equations given in *Table 2.3.1 Plate panel buckling requirements* for the above load fields are complied with.

Table 2.3.1 Plate panel buckling requirements

	Stress field	Buckling interaction formula	
(a)	uni-axial compressive loads	$\frac{\sigma_{d}}{\sigma_{c}} \le 1,0\frac{1}{\lambda_{\sigma}}$	
(b)	shear loads	$\frac{\tau_{d}}{\tau_{c}} \le \frac{1}{\lambda_{\tau}}$	
(c)	bi-axial compressive loads	for A_R = 1,0 $\frac{\sigma_{dx}}{\sigma_{cx}} + \frac{\sigma_{dy}}{\sigma_{cy}} \le 1,0$ for other aspect ratios, i.e. $A_R \neq 1,0$ $\frac{\sigma_{dx}}{\sigma_{cx}} + \frac{\sigma_{dy}}{\sigma_{cy}} \le G$ when G is taken from *Figure 2.3.3 Interaction limiting stress curves of G for plate panels subject to bi-axial compression, see Table 2.3.2(c)*	
(d)	uni-axial compressive loads plus shear load	for $A_R > 1$ $\left(\frac{\sigma_{d}}{\sigma_{c}}\right) + \left(\frac{\tau_{d}}{\tau_{c}}\right)^2 \le 1$ for $A_R \le 1$ $\left(\frac{1+0,6A_R}{1,6}\right)\left(\frac{\sigma_{d}}{\sigma_{c}}\right) + \left(\frac{\tau_{d}}{\tau_{c}}\right)^2 \le 1$	
(e)	bi-axial compressive loads plus shear loads	$0,25\frac{\left(1+\frac{0,6}{A_R}\right)\left(\frac{\sigma_{dy}}{\sigma_{cy}}\right)}{1-0,625\left(\sigma_{cx}\right)} + \frac{\left(\frac{\tau_{d}}{\tau_{c}}\right)^2}{1-\left(\frac{\sigma_{dx}}{\sigma_{cx}}\right)} \le 1$	

Symbols		
σ_d	=	design compressive stress, *see Vol 1, Pt 6, Ch 2, 3.1 General 3.1.3*
σ_c	=	critical compressive buckling stress, in N/mm^2, for uniaxial compressive load acting independently, *see Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements 3.3.5*
σ_{dx}	=	design compressive stress in x direction
σ_{dy}	=	design compressive stress in the y direction
σ_{cx}	=	critical compressive buckling stress in x direction, *see Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements 3.3.5*
σ_{cy}	=	critical compressive buckling stress in y direction, *see Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements 3.3.5*
λ_σ	=	buckling factor of safety for compressive stresses, *see Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements 3.3.4*
λ_τ	=	buckling factor of safety for shear stresses, *see Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements 3.3.4*
τ_d	=	design shear stress, in N/mm^2
τ_c	=	critical shear buckling stress, in N/mm^2, acting independently, *see Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements 3.3.5*

3.3.3 The critical compressive buckling stresses and critical shear buckling stresses required for *Table 2.3.1 Plate panel buckling requirements* are to be derived in accordance with *Vol 1, Pt 6, Ch 2, 3.4 Derivation of the buckling stress for plate panels*

3.3.4 The buckling factors of safety λ_σ and λ_τ required by *Table 2.3.1 Plate panel buckling requirements* are to be extracted from *Vol 1, Pt 6, Ch 5 Structural Design Factors* for the structural member concerned.

3.3.5 For all structural members which contribute to the hull girder strength, the plate panel buckling requirements for uni-axial compressive loads, *Table 2.3.1 Plate panel buckling requirements*, and shear loads, *Table 2.3.1 Plate panel buckling requirements* are to be complied with.

3.3.6 In addition to *Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements 3.3.5*, structural members which are subjected to local compressive loads and/on shear loads are to be verified using the plate panel buckling requirements in *Table 2.3.1 Plate panel buckling requirements* to *Table 2.3.1 Plate panel buckling requirements*.

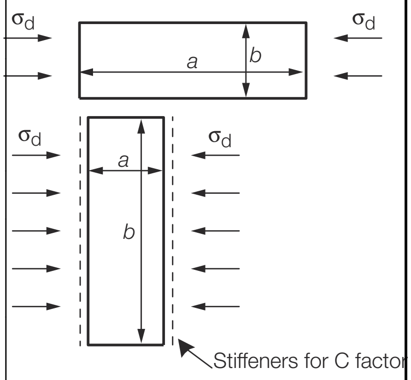
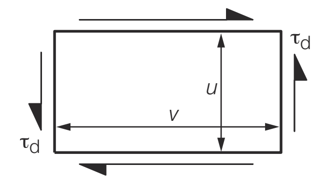
3.3.7 However, where some members of the structure have been designed such that elastic buckling of the plate panel between the stiffeners is allowable, then the requirements of *Vol 1, Pt 6, Ch 2, 3.5 Additional requirements for plate panels which buckle elastically* must be applied to the buckling analysis of the stiffeners supporting the plating. In addition, panels which do not satisfy the panel buckling requirements must be indicated on the appropriate drawing and the effect of these panels not being effective in transmitting compressive loads taken into account for the hull girder strength calculation, *see Vol 1, Pt 6, Ch 4, 1.4 Calculation of hull section modulus 1.4.7* and *Vol 1, Pt 6, Ch 4, 1.4 Calculation of hull section modulus 1.4.8*

3.3.8 In general the plate panel buckling requirements for more complex load fields, *see Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements 3.3.1*, *Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements 3.3.1* and *Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements 3.3.1*, are to be complied with. Where this is not possible, due to elastic buckling of the panel, then the critical buckling stress, σ_c, may be based on the ultimate collapse strength of the plating, σ_u from *Vol 1, Pt 6, Ch 2, 3.5 Additional requirements for plate panels which buckle elastically 3.5.4*, instead of the elastic buckling stress, σ_e, derived in *Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements 3.3.5*. In addition, the requirements of *Vol 1, Pt 6, Ch 2, 3.5 Additional requirements for plate panels which buckle elastically* are to be met for the supporting secondary stiffeners and primary members.

3.4 Derivation of the buckling stress for plate panels

3.4.1 The critical compressive buckling stress, σ_c, for a plate panel subjected to uni-axial in-plane compressive loads is to be derived in accordance with *Table 2.3.2 Buckling stress of plate panels*

Table 2.3.2 Buckling stress of plate panels

Mode	Elastic buckling stress, N/mm^2 *see* Note	
(a) Uni-axial compression: (i) Long narrow panels, loaded on the narrow edge (ii) Short broad panels, loaded on the broad edge	$A_R \geq 1$ $\sigma_e = 3,62\,\varphi\,E\left(\frac{t_p}{b}\right)^2$ $A_R < 1$ $\sigma_e = 0,9C\,\varphi\left(\frac{b}{a}+\frac{a}{b}\right)^2 E\left(\frac{t_p}{b}\right)^2$	
(b) Pure shear:	$\tau_e = 3,62\left(1,335+\left(\frac{u}{v}\right)^2\right)E\left(\frac{t_p}{u}\right)^2$ NOTE*u* is to be the minimum dimension	

NOTE
The critical buckling stresses, in N/mm^2, are to be derived from the elastic buckling stresses as follows:

$\sigma_c = \sigma_e$ when $\sigma_e < \frac{\sigma_o}{2}$

$= \sigma_o\left(1-\frac{\sigma_o}{4\sigma_e}\right)$ when $\sigma_e \geq \frac{\sigma_o}{2}$

$\tau_c = \tau_e$ when $\tau_e < \frac{\tau_o}{2}$

$= \tau_o\left(1-\frac{\tau_o}{4\tau_e}\right)$ when $\tau_e \geq \frac{\tau_o}{2}$

σ_c = is defined in *Vol 1, Pt 6, Ch 2, 3.2 Symbols 3.2.1*

σ_o = is defined in *Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*

τ_c = is defined in *Vol 1, Pt 6, Ch 2, 3.2 Symbols 3.2.1*

τ_o = is defined in *Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*

Symbols and definitions

A_R = panel aspect ratio, *see Vol 1, Pt 6, Ch 2, 3.2 Symbols 3.2.1*

σ_e = elastic compressive buckling stress, in N/mm^2

τ_e = elastic shear buckling stress, in N/mm^2

a and *b* are the panel dimensions in mm, *see* figures above

t_p = thickness of plating, in mm

Φ = stress distribution factor for linearly varying compressive stress across plate width

= $0{,}47\mu^2 - 1{,}4\mu + 1{,}93$ for $\mu \geq 0$

= 1 for constant stress

μ = $\dfrac{\sigma_{d1}}{\sigma_{d2}}$ where σ_{d1} and σ_{d2} are the smaller and larger average compressive stresses respectively

E = Young's Modulus of elasticity of material, in N/mm^2

C = stiffener influence factor for panels with stiffeners perpendicular to compressive stress

= 1,3 when plating stiffened by floors or deep girders

= 1,21 when stiffeners are built up profiles or rolled angles

= 1,10 when stiffeners are bulb flats

= 1,05 when stiffeners are flat bars

= σ_d and τ_d are the design compressive and design shear stresses in the direction illustrated in the figures. With linearly varying stress across the plate panel, σ_d is to be taken as σ_{d2}.

3.4.2 The critical shear buckling stress, τ_c, for a plate panel subjected to pure in-plane shear load is to be derived in accordance with *Table 2.3.2 Buckling stress of plate panels*.

3.4.3 For welded plate panels with plating thicknesses below 8 mm, the critical compressive buckling stress is to be reduced to account for the presence of residual welding stresses. The critical buckling stress for plating is to be taken as the minimum of:

$$\sigma_{cr} = \sigma_e - \sigma_r$$

or

σ_c = as derived using *Vol 1, Pt 6, Ch 2, 3.4 Derivation of the buckling stress for plate panels 3.4.1*

where

σ_r = reduction in compressive buckling stress due to residual welding stresses

$$= \frac{2\beta_{RS}\sigma_o}{b/t_p}$$

β_{RS} = residual stress coefficient dependent on type of weld (average value of β_{RS} to be taken as 3)

t_p and σ_o are defined in *Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*

σ_c is derived in *Vol 1, Pt 6, Ch 2, 3.4 Derivation of the buckling stress for plate panels 3.4.1*

b is defined in *Vol 1, Pt 6, Ch 2, 3.2 Symbols 3.2.1*

3.4.4 In general the effect of lateral loading on plate panels (for example hydrostatic pressure on bottom shell plating) may be neglected and the critical buckling stresses calculated considering the in-plane stresses only.

3.4.5 Unless indicated otherwise, the effect of initial deflection on the buckling strength of plate panels may be ignored.

3.5 Additional requirements for plate panels which buckle elastically

3.5.1 Elastic buckling of plate panels between stiffeners occurs when both the following conditions are satisfied:

(a) The design compressive stress, σ_d, is greater than the elastic buckling stress of the plating, σ_e

$$\sigma_d > \sigma_e$$

(a) The elastic buckling stress is less than half the yield stress

$$\sigma_e \leq \frac{\sigma_o}{2}$$

3.5.2 Elastic buckling of local plating between stiffeners, including girders or floors etc. may be allowed if all of the following conditions are satisfied:

(a) The critical buckling stress of the stiffeners in all buckling modes is greater than the axial stress in the stiffeners after redistribution of the load from the elastically buckled plating into the stiffeners, hence

$$\frac{\sigma_{de}}{\sigma_{c(i)}} \leq \frac{1}{\lambda\ \sigma}$$

= where

i = (a), (t), (w) or (f)

(a) Maximum predicted loadings are used in the calculations.

(b) Functional requirements will allow a degree of plating deformation.

where

σ_{de} is the stiffener axial stress given in *Vol 1, Pt 6, Ch 2, 3.5 Additional requirements for plate panels which buckle elastically 3.5.5*

$\sigma_{c(i)}$ is given by *Table 2.3.3 Buckling stress of secondary stiffeners*

where
i is a, t, w or f depending on the mode of buckling.

λ_σ is the buckling factor of safety given in *Table 5.3.2 Allowable stress factors f 1*.

3.5.3 The effective breadth of attached plating for stiffeners, girder or beams that is to be used for the determination of the critical buckling stress of the stiffeners attached to plating which buckles elastically is to be taken as follows:

$$b_{eu} = \frac{b\ \sigma_u}{\sigma_o}\ \text{mm}$$

where

σ_u = ultimate buckling strength of plating as given in *Vol 1, Pt 6, Ch 2, 3.5 Additional requirements for plate panels which buckle elastically 3.5.4*

σ_o = is defined in *Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*

b_{eu} = effective panel breadth perpendicular to direction of compressive stress being considered

b is given in *Vol 1, Pt 6, Ch 2, 3.2 Symbols 3.2.1*

3.5.4 The ultimate buckling strength of plating, σ_u, which buckles elastically, may be determined as follows:

(a) shortest edge loaded, i.e. $A_R \geq 1$:

$$\sigma_u = \sigma_o\left(\frac{1,9}{W} - \frac{0,8}{W^2}\right)\text{N/mm}^2$$

(b) longest edge loaded i.e. $A_R < 1$:

$$\sigma_u = \frac{1,77\ \sigma_o A_R^{0,78}}{W}\text{N/mm}^2$$

where

$$W = \frac{s}{t_p}\sqrt{\frac{\sigma_o}{E}}$$

A_R and *s* are defined in *Vol 1, Pt 6, Ch 2, 3.2 Symbols 3.2.1*

t_p, E and σ_{ow} are defined in *Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*.

3.5.5 The axial stress in stiffeners attached to plating which is likely to buckle elastically is to be derived as follows:

$$\sigma_{de} = \sigma_d \frac{A_t}{A_{tb}}$$

where

σ_d is the axial stress in the stiffener when the plating can be considered fully effective

$$A_t = A_s + \frac{bt}{100}\,\mathrm{cm}^2$$

$$A_{tb} = A_s + \frac{b_{eu}t}{100}\,\mathrm{cm}^2$$

where

b and b_{eu} are given in *Vol 1, Pt 6, Ch 2, 3.5 Additional requirements for plate panels which buckle elastically 3.5.3*

t is the plating thickness, in mm

A_s is the stiffener area in cm^2.

3.6 Shear buckling of stiffened panels

3.6.1 The shear buckling capability of longitudinally stiffened panels between primary members is to satisfy the following condition:

$$\frac{\tau_d}{\tau_c} \leq \frac{1}{\lambda_\tau}$$

where

τ_c is derived from *Vol 1, Pt 6, Ch 2, 3.6 Shear buckling of stiffened panels 3.6.3*

τ_d is the design shear stress

λ_τ is given in *Table 5.3.2 Allowable stress factors f 1*.

3.6.2 The elastic shear buckling stress of longitudinally stiffened panels between primary members may be taken as:

$$\tau_e = K_s E\left(\frac{t}{s}\right)^2 \text{for } A_R \geq 1$$

where

K_s = $4,5\left(\left(\frac{s}{1000l}\right)^2 + \frac{1}{N^2} + \left(\frac{N^2-1}{N^2}\right)\left(\frac{\omega}{1+\omega}\right)^r\right)$

N = number of subpanels

= $\frac{1000S_p}{s}$

ω = $\frac{10I_{se}}{l\,t^3}$

I_{se} = moment of inertia of a section, in cm^4, consisting of the longitudinal stiffener and a plate flange of effective width s/2

r = $1 - 0,75\left(\frac{s}{1000l}\right)$

s, l, E and S_p are as defined in *Vol 1, Pt 6, Ch 2, 3.2 Symbols 3.2.1*, *see also Figure 2.3.1 Shear buckling*

3.6.3 The critical shear buckling stress, τ_c, may be determined from τ_e, *see* Note in *Table 2.3.2 Buckling stress of plate panels*.

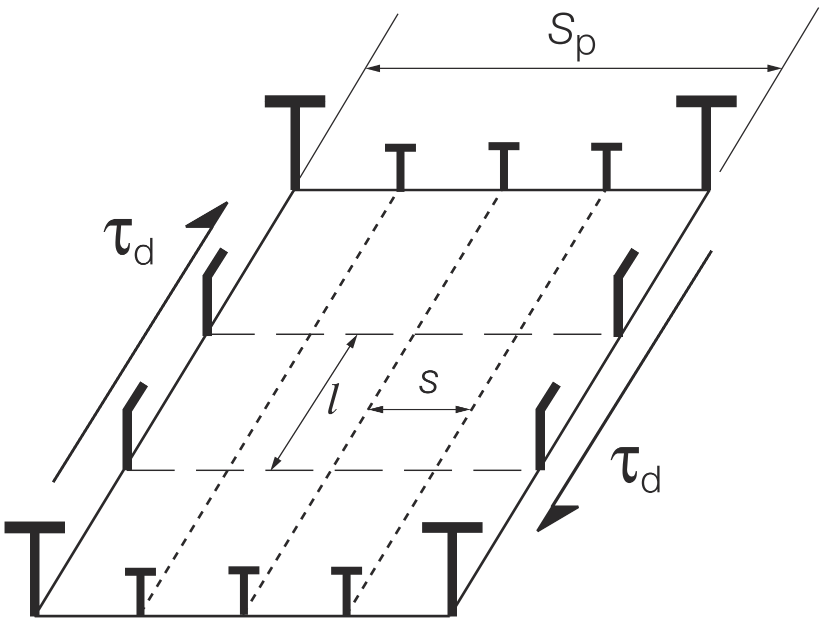


Figure 2.3.1 Shear buckling

3.7 Secondary stiffening in direction of compression

3.7.1 The buckling performance of stiffeners will be considered satisfactory if the following conditions are satisfied:

$$\frac{\sigma_d}{\sigma_{c(a)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(t)}} \leq \frac{1}{\lambda_\sigma}$$

$$\frac{\sigma_d}{\sigma_{c(w)}} \leq \frac{1}{\lambda_\sigma} \qquad \frac{\sigma_d}{\sigma_{c(f)}} \leq \frac{1}{\lambda_\sigma}$$

where

$\sigma_{C\ (a)}$, $\sigma_{C\ (t)}$, $\sigma_{C\ (w)}$ and $\sigma_{C\ (f)}$ are the critical buckling stress of the stiffener for each mode of failure, *see Vol 1, Pt 6, Ch 2, 3.7 Secondary stiffening in direction of compression 3.7.2*

σ_d is the design compressive stress, *see also Vol 1, Pt 6, Ch 2, 3.1 General 3.1.3* and *Vol 1, Pt 6, Ch 2, 3.5 Additional requirements for plate panels which buckle elastically*

λ_σ is the buckling factor of safety given in *Table 5.3.2 Allowable stress factors f 1* in *Vol 1, Pt 6, Ch 5 Structural Design Factors* The value of λ_σ to be chosen depends on the buckling assessment of the attached plating, *see* Note 3, *Table 5.3.2 Allowable stress factors f 1*

3.7.2 The critical buckling stresses for the overall, torsional, web and flange buckling modes of longitudinals and secondary stiffening members under axial compressive loads are to be determined in accordance with *Table 2.3.3 Buckling stress of secondary stiffeners*

Table 2.3.3 Buckling stress of secondary stiffeners

Mode	Elastic buckling stress, N/mm^2	Critical buckling stress, N/mm^2 *see* Note
(a) Overall buckling (perpendicular to plane of plating without rotation of cross-section)	$\sigma_{e(a)} = C_f 0,001E\frac{I_a}{A_{te}l_e^2}$	$\sigma_{c(a)}$

(b) Torsional buckling	$\sigma_{e(t)} = \frac{0,001 E I_w}{I_p l_e^2}\left(m^2 + \frac{K}{m^2}\right) + 0,385 E \frac{I_t}{I_p}$	$\sigma_{c(t)}$
(c) Web buckling (excluding flat bar stiffeners)	$\sigma_{e(w)} = 3,8 E \left(\frac{t_w}{d_w}\right)^2$	$\sigma_{c(w)}$
(d) Flange buckling	$\sigma_{e(f)} = 3,8 E \left(\frac{t_f}{b_f}\right)^2$	$\sigma_{c(f)}$

NOTE
The critical buckling stresses are to be derived from the elastic buckling stresses as follows:

σ_c = σ_e when $\sigma_e < \frac{\sigma_o}{2}$

= $\sigma_o\left(1 - \frac{\sigma_o}{4\sigma_e}\right)$ when $\sigma_e \geq \frac{\sigma_o}{2}$

Symbols

d_w = web depth, in mm, (excluding flange thickness for rolled sections), *see Figure 2.2.1 Dimensions of longitudinals*

t_w = web thickness, in mm

b_f = flange width, in mm (including web thickness)

t_f = flange thickness, in mm. For bulb plates, the mean thickness of the bulb may be used, *see Figure 2.2.1 Dimensions of longitudinals*

l_e = effective span length of stiffener, in metres

C_f = end constraint factor

= 1 where both ends are pinned

= 2 where one end is pinned and the other end fixed

= 4 where both ends are fixed

E = Young's Modulus of elasticity of the material, in N/mm^2

I_a = moment of inertia, in cm^4, of longitudinal, including attached plating of effective width b_{eb}. For stiffeners attached to plating which buckles elastically, *see* 4.5, the effective width of plating is to be taken as b_{eu}.

t_p and σ_o are given in *Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*
A_{te} and b_{eb} are given in *Vol 1, Pt 6, Ch 2, 3.2 Symbols 3.2.1*

I_t = St.Venant's of inertia, in cm^4, of longitudinal (without attached plating)

$= \dfrac{d_w t_w^3}{3} 10^{-4}$ for flat bars

$= \dfrac{1}{3}\left[d_w t_w^3 + b_f t_f^3\left(1 - \dfrac{0,63 t_f}{b_f}\right)\right] 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_p = polar moment of inertia, in cm^4, of profile about connection of stiffener to plating

$= \dfrac{d_w^3 t_w}{3} 10^{-4}$ for flat bars

$= \left(\dfrac{d_w^3 t_w}{3} + d_w^2 b_f t_f\right) 10^{-4}$ for built up profiles, rolled angles and bulb plates

I_w = sectional moment of inertia, in cm^6, of profile and connection of stiffener to plating

$= \dfrac{d_w^3 t_w^3}{36} 10^{-6}$ for flat bars

$= \dfrac{t_f b_f^3 d_w^2}{12} 10^{-6}$ for 'Tee' profiles

$= \dfrac{b_f^3 d_w^2}{12\left(b_f + d_w\right)^2}\left(t_f\left(b_f^2 + 2b_f d_w + 4d_w^2\right) + 3t_w b_f d_w\right) 10^{-6}$ for '*L*' profiles, rolled angles and bulb plates

C = spring stiffness exerted by supporting plate panel

$$= \frac{k_p E t_p^3}{3b\left(1 + \dfrac{1,33 k_p d_w t_p^3}{b t_w^3}\right)}$$

k_p = 1 – η_p, and is not to be taken as less than zero. For built up profiles, rolled angles and bulb plates, k_p need not be taken less than 0,1

η_p = $\dfrac{\sigma_d}{\sigma_{ep}}$

σ_{ep} = elastic critical buckling stress, in N/mm^2, of the supporting plate derived from *Table 2.4.1 First mode of vibration constant K i*

m is determined as follows: e.g.*m* = 2 for *K* = 25

K range	$0 \leq k < 4$	$4 \leq k < 36$	$36 \leq k < 144$	$144 \leq k < 400$	$400 \leq k < 900$	$900 \leq k < 1764$	$(m - 1)^2 m^2 \leq k < m^2 (m + 1)^2$

m	1	2	3	4	5	6	m

$$K = \frac{1,03CS^4}{E\,I_w}10^4$$

σ_d is the design stress, in N/mm^2

all other symbols as defined in *Vol 1, Pt 6, Ch 2, 3.2 Symbols 3.2.1* or *Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*.

3.7.3 To prevent torsional buckling of secondary stiffeners from occurring before buckling of the plating, the critical torsional buckling stress, $\sigma_{c(t)}$, is to be greater than the critical buckling stress of the attached plating as detailed in *Vol 1, Pt 6, Ch 2, 3.4 Derivation of the buckling stress for plate panels 3.4.1*

3.7.4 The critical buckling stresses of the stiffener web, $\sigma_{c(w)}$, and flange, $\sigma_{c(f)}$, are to be greater than the critical torsional buckling stress, hence:

$\sigma_{c(w)} > \sigma_{c(t)}$

$\sigma_{c(f)} > \sigma_{c(t)}$

3.7.5 To ensure that overall buckling of the stiffened panel cannot occur before local buckling of the secondary stiffener, the critical overall buckling stress $\sigma_{c(a)}$, is to be greater than the critical torsional buckling stress, hence:

$\sigma_{c(a)} > \sigma_{c(t)}$

3.8 Secondary stiffening perpendicular to direction of compression

3.8.1 Where a stiffened panel of plating is subjected to a compressive load perpendicular to the direction of the stiffeners, *see Figure 2.3.2 Secondary stiffening perpendicular to direction of compression* e.g. a transversely stiffened panel subject to longitudinal compressive load, the requirements of this section are to be applied.

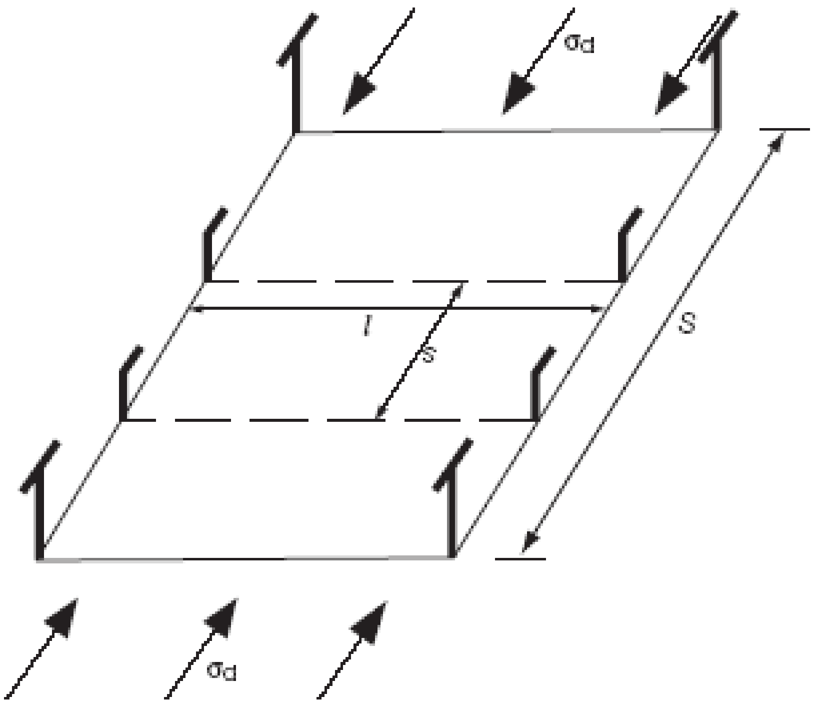


Figure 2.3.2 Secondary stiffening perpendicular to direction of compression

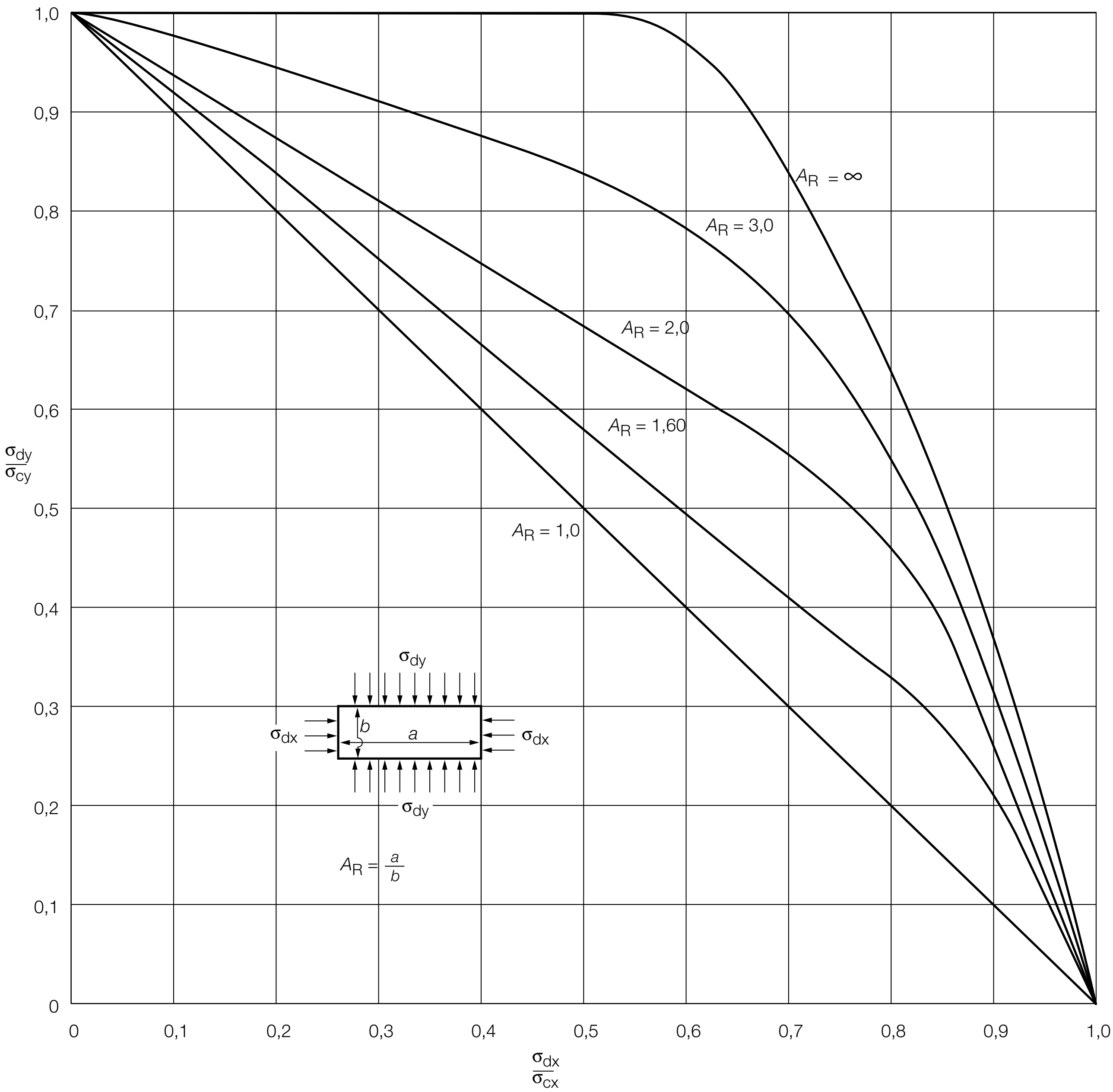


Figure 2.3.3 Interaction limiting stress curves of G for plate panels subject to bi-axial compression, *see* Table 2.3.2(c)

3.8.2 The minimum moment of inertia of each stiffener including attached effective plating of width, b_{eb}, to ensure that overall panel buckling does not precede plate buckling is to be taken as:

$$I_s = \frac{D\,s\left(4N_L^2 - 1\right)\left(\left(N_L^2 - 1\right)^2 - 2\left(N_L^2 - 1\right)\kappa + \kappa^2\right)}{2\left(5N_L^2 + 1 - \kappa\right)\Pi^4 E}\ \text{mm}^4$$

where

D = $\dfrac{Et^{3}_{\text{p}}}{12\left(1 - \upsilon^{2}\right)}$

$\boldsymbol{\kappa}$ = $A_{\text{R}}^{2}\,\Pi^{2}$

A_{R} = plate panel aspect ratio

= $\dfrac{s}{1000l}$

$\boldsymbol{\Pi}$ = $\dfrac{S}{l}$

N_{L} = number of plate panels

N_{L}–1 = number of stiffeners

$\boldsymbol{\upsilon}$ = 0,3

s, l and S are defined in *Vol 1, Pt 6, Ch 2, 3.2 Symbols 3.2.1* and shown in *Figure 2.3.2 Secondary stiffening perpendicular to direction of compression*

t_{p} and E are defined in *Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*.

3.9 Buckling of primary members

3.9.1 Where primary girders are subject to axial compressive loading, the buckling requirements for lateral, torsional, web and flange buckling modes detailed in *Vol 1, Pt 6, Ch 2, 3.7 Secondary stiffening in direction of compression* are to be satisfied.

3.9.2 To prevent global buckling from occurring before local panel buckling, transverse primary girders supporting axially loaded longitudinal stiffeners are to have a sectional moment of inertia, including attached plating, of not less than the following:

$$I_{\text{g}} = \frac{0,35S^{4}_{\text{P}}I_{\text{s}}}{l^{3}s} \times 10^{3}\text{cm}^{4}$$

S_{p} and s are as defined in *Vol 1, Pt 6, Ch 2, 3.2 Symbols 3.2.1*

I_{g} = is the sectional moment of inertia including attached plating

I_{s} = moment of inertia of secondary stiffeners, in cm^4, required to satisfy the elastic column buckling mode specified in *Table 2.3.3 Buckling stress of secondary stiffeners*

= $\dfrac{\sigma_{\text{ep}}A_{\text{te}}l_{\text{e}}^{2}}{0,001E}$

where

$\boldsymbol{\sigma}_{\text{ep}}$ = $1,2\,\sigma_{\text{d}}\,\text{N/mm}^{2}\text{ for }\sigma_{\text{e(a)}} < \dfrac{\sigma_{\text{o}}}{2}$

= $\dfrac{\sigma_{o}^{2}}{4\left(\sigma_{o} - 1,2\,\sigma_{\text{d}}\right)}\text{ for }\sigma_{\text{e(a)}} \geq \dfrac{\sigma_{o}}{2}$

σ_{d} is design stress, in N/mm^2

σ_{o} and A_{te} are as defined in *Vol 1, Pt 6, Ch 2, 3.2 Symbols 3.2.1*

$\sigma_{\text{e(a)}}$ is the elastic column buckling stress, *see Vol 1, Pt 6, Ch 2, 3.7 Secondary stiffening in direction of compression 3.7.2*

E is defined in *Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*

l_{e} is defined in *Table 2.3.3 Buckling stress of secondary stiffeners*

3.10 Shear buckling of girder webs

3.10.1 Local panels in girder webs subject to in-plane shear loads are to satisfy the shear buckling requirements in *Table 2.3.1 Plate panel buckling requirements*, item (b).

3.10.2 The critical shear buckling stress, τ_c, is to be determined using the following formula for τ_e and the Note in *Table 2.3.2 Buckling stress of plate panels*

$$\tau_e = 3,62\left(1,335 + \left(\frac{d_w}{1000 l_p}\right)^2\right) E \left(\frac{t_p}{d_w}\right)^2 \text{N/mm}^2$$

where

d_w = web height, in mm

l_p = unsupported length of web, in metres

t_p and E are defined in *Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*

3.11 Pillars and pillar bulkheads

3.11.1 Pillars and pillar bulkheads are to comply with the requirements of *Vol 1, Pt 6, Ch 3, 12 Pillars and pillar bulkheads*

■ *Section 4*
Vibration control

4.1 General

4.1.1 Natural frequencies are to be investigated for local unstiffened and stiffened panels expected to be exposed to excessive structural vibrations being induced from machinery, propulsion unit or other potential excitation sources.

4.1.2 Where the structural configurations are such that basic structural elements may be modelled individually the natural frequencies may be derived in accordance with *Vol 1, Pt 6, Ch 2, 4.3 Natural frequency of plate*, *Vol 1, Pt 6, Ch 2, 4.4 Natural frequency of plate and stiffener combination* and *Vol 1, Pt 6, Ch 2, 4.5 Effect of submergence*, as appropriate. Under other circumstances, finite element analysis is to be employed to evaluate the vibration characteristics of the structure considered.

4.2 Frequency band

4.2.1 The natural frequency of panels is generally not to lie within a band of ±20 per cent of a significant excitation frequency.

4.3 Natural frequency of plate

4.3.1 The natural frequency of an homogeneous clamped plate in air is given by the following:

$$f_{air} = 5537 \frac{t_p}{ls}\sqrt{\left(\frac{1000l}{s}\right)^2 + \left(\frac{s}{1000l}\right)^2 + 0,6045} \text{ Hz}$$

where

l = panel length, in metres

s = panel breadth, in mm

t_p = panel thickness, in mm.

4.4 Natural frequency of plate and stiffener combination

4.4.1 The natural frequency of a plate stiffener of constant cross-section in air is given by the following:

$$f_{air} = \frac{k_i}{20\,\pi\, l_b^2}\sqrt{\frac{El}{m\left(1+\frac{\pi^2 El}{10^4 l_b^2 GA}\right)}}\ \text{Hz}$$

where

l_b = length of stiffener, in metres

m = mass per unit length of the stiffener and associated plating, in kg/m

K_i = constant where i refers to the mode of vibration as given in *Table 2.4.1 First mode of vibration constant K i*

G = shear modulus of elasticity, in N/mm^2.

A = shear area of stiffener, in cm^2

I = Inertia of stiffener, in cm^4

E = modulus of elasticity, in N/mm^2

Table 2.4.1 First mode of vibration constant K_i

End condition	Mode				
	1	2	3	4	5
Simply supported	9,92	—	—	—	—
Fixed ends	22,40	61,70	121,0	200,0	299,0
Simple and fixed	15,4	—	—	—	—

4.5 Effect of submergence

4.5.1 To obtain the frequency, f_{water}, of a plate with one side exposed to air and the other side exposed to a liquid, the frequency calculated in air f_{air} may be modified by the following formula:

$$f_{water} = f_{air}\sqrt{\frac{K_p}{K_p + \frac{\rho_1}{\rho_p}}}$$

where

ρ_l = density of the liquid, in kg/m^3

ρ_p = density of the plate, in kg/m^3

κ_p = $\dfrac{\pi\, t_p}{l\, s}\sqrt{\dfrac{s^2}{10^6} + l^2}$

where l, s and t_p are as defined in *Vol 1, Pt 6, Ch 2, 4.3 Natural frequency of plate 4.3.1*

Section 5
Dynamic loading

5.1 General

5.1.1 The following formulae are to be used to determine the dynamic response of plate and plate stiffener combinations. The natural frequency of structural items can be determined from *Vol 1, Pt 6, Ch 2, 4 Vibration control* and the period T may then be determined as follows:

$$T = \frac{1}{f} \text{ seconds}$$

where

f = the natural frequency and is normally to be taken as f_{air}, *see Vol 1, Pt 6, Ch 2, 4.3 Natural frequency of plate 4.3.1* for plating or *Vol 1, Pt 6, Ch 2, 4.4 Natural frequency of plate and stiffener combination 4.4.1* for plate and stiffener combination.

5.1.2 For bottom impact pressure loads and bow flare and above waterline impact pressure loads required by *Vol 1, Pt 6, Ch 3, 14 Strengthening for bottom slamming* and *Vol 1, Pt 6, Ch 3, 15 Strengthening for wave impact loads above waterline* respectively, the impact pressure is assumed to be represented by a triangular pulse load. The rise time, t_1, for these impact pressures is given in *Vol 1, Pt 5, Ch 3, 4.2 Bottom impact pressure, IPbi 4.2.2* for bottom impact and *Vol 1, Pt 5, Ch 3, 4.3 Bow flare and wave impact pressures, IPbf 4.3.2* for bow flare impact.

5.2 Gradually applied load

5.2.1 For a gradually applied load as shown in *Figure 2.5.1 Gradually applied load* the maximum dynamic load factor f_{DLF} can be calculated as from *Table 2.5.1 Tabulated dynamic load factors*. Linear interpolation may be performed to obtain f_{DLF} values for intermediate t_1/T values.

5.2.2 The time to maximum response can be calculated from *Table 2.5.1 Tabulated dynamic load factors* with intermediate values determined by linear interpolation.

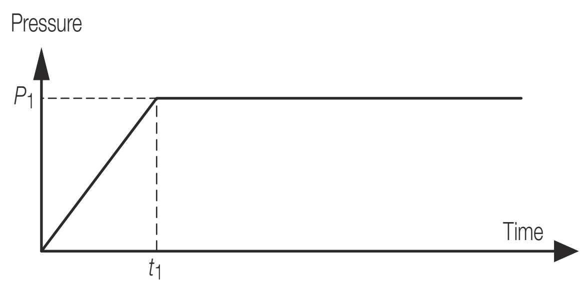


Figure 2.5.1 Gradually applied load

5.3 Instantaneous load

5.3.1 For an instantaneous applied load as shown in *Figure 2.5.2 Instantaneous pulse load* the maximum dynamic load factor f_{DLF} can be calculated as from *Table 2.5.1 Tabulated dynamic load factors* Linear interpolation may be performed to obtain f_{DLF} values for intermediate t_1/T values. The t_1 time value is given in the same section that the impulsive pressure load is specified.

5.3.2 The time to maximum response can be calculated from *Table 2.5.1 Tabulated dynamic load factors* with intermediate values determined by linear interpolation.

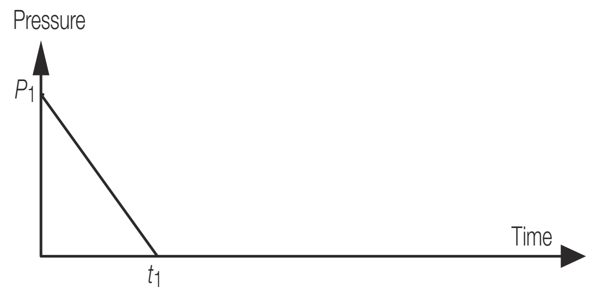


Figure 2.5.2 Instantaneous pulse load

5.4 Triangular pulse load

5.4.1 For a triangular pulse load as shown in *Figure 2.5.3 Triangular pulse load*, the maximum dynamic load factor DLF be calculated from *Table 2.5.1 Tabulated dynamic load factors*. Linear interpolation may be performed to obtain DLF Rules for intermediate t_1/T values. The t_1 time value is given in the same section that the impulsive pressure load is specified.

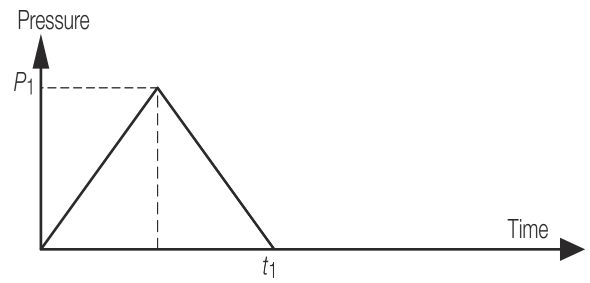


Figure 2.5.3 Triangular pulse load

5.4.2 The time to maximum response can be calculated from *Table 2.5.1 Tabulated dynamic load factors* with intermediate values determined by linear interpolation.

Table 2.5.1 Tabulated dynamic load factors

	Dynamic load factor			Time to maximum displacement		
t_1/T	Gradual f_{DLF}	Triangular f_{DLF}	Instant f_{DLF}	Gradual t_m/t_1	Triangular $t_m/2t_1$	Instant t_m/T
0,0	2,0	0,0	0,0			
0,1	1,984	0,312	0,300	5,800	2,484	0,284
0,2	1,935	0,608	0,600	3,000	1,700	0,316
0,3	1,858	0,875	0,850	2,100	1,361	0,348
0,4	1,757	1,098	1,050	1,700	1,163	0,381
0,5	1,637	1,273	1,200	1,450	1,029	0,400
0,6	1,504	1,391	1,300	1,280	0,931	0,415
0,7	1,363	1,465	1,400	1,150	0,856	0,430

0,8	1,232	1,501	1,480	1,080	0,795	0,440
0,9	1,109	1,514	1,530	1,010	0,746	0,445
1,0	1,000	1,508	1,600	1,000	0,704	0,450
				1,500(1)		
1,1	1,089	1,481	1,630	1,430	0,668	0,453
1,2	1,156	1,441	1,660	1,360	0,637	0,456
1,3	1,198	1,397	1,690	1,290	0,609	0,459
1,4	1,216	1,342	1,715	1,220	0,585	0,462
1,5	1,212	1,282	1,725	1,150	0,563	0,465
1,6	1,189	1,228	1,730	1,119	0,544	0,466
1,7	1,151	1,165	1,730	1,089	0,526	0,468
1,8	1,104	1,104	1,745	1,059	0,510	0,469
1,9	1,052	1,052	1,748	1,029	0,495	0,471
2,0	1,000	1,000	1,750	1,200	0,481	0,473
2,1	1,047	0,960	1,756	1,170	0,520	0,474
2,2	1,085	0,953	1,763	1,140	0,540	0,475
2,3	1,111	0,980	1,769	1,110	0,560	0,477
2,4	1,125	1,016	1,775	1,080	0,580	0,478
2,5	1,127	1,055	1,781	1,050	0,600	0,480
2,6	1,116	1,089	1,786	1,039	0,590	0,480
2,7	1,095	1,115	1,79	1,029	0,580	0,480
2,8	1,067	1,126	1,797	1,019	0,570	0,481
2,9	1,034	1,135	1,802	1,009	0,560	0,481
3,0	1,000	1,158	1,800	1,100	0,550	0,482
3,1	1,032	1,168	1,800	1,089	0,545	0,482
3,2	1,059	1,167	1,808		0,540	0,483
3,3	1,078	1,155	1,812		0,535	0,483
3,4	1,089	1,132	1,817		0,530	0,484
3,5	1,091	1,103	1,821		0,525	0,484
3,6	1,084	1,084	1,825		0,520	0,485
3,7	1,070	1,070	1,829		0,515	0,485
3,8	1,059	1,060	1,833		0,510	0,486
3,9	1,025	1,025	1,837		0,505	0,486
4,0	1,000	1,000	1,825		0,500	0,487
4,1	1,024	0,978	1,828		0,505	0,487
4,2	1,045	0,976	1,831		0,510	0,487
4,3	1,060	0,989	1,835		0,515	0,487
4,4	1,069	1,007	1,838		0,520	0,488

4,5	1,071	1,029	1,842		0,525	0,488
4,6	1,066	1,050	1,845		0,530	0,488
4,7	1,055	1,069	1,849		0,535	0,489
4,8	1,039	1,083	1,852		0,540	0,489
4,9	1,020	1,091	1,855		0,545	0,489
5,0	1,000	1,092	1,850		0,550	0,490
5,1	1,019	1,083	1,853		0,545	0,490
5,2	1,036	1,069	1,856		0,540	0,490
5,3	1,049	1,050	1,859		0,535	0,490
5,4	1,056	1,056	1,862		0,530	0,490
5,5	1,058	1,058	1,865		0,525	0,490
5,6	1,054	1,054	1,868		0,520	0,490
5,7	1,045	1,045	1,870		0,515	0,490
5,8	1,032	1,032	1,873		0,510	0,490
5,9	1,017	1,017	1,876		0,505	0,490
≥6,0	1,002	1,002	1,870		0,500	0,491

NOTE

The time to maximum displacement curve for a gradually applied load has a step at $t_1/T = 1,0$.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to monohull craft of steel construction as defined in *Vol 1, Pt 1, Ch 2, 2 Scope of the Rules*

1.1.2 All NS1, NS2 and NS3 ships as defined in *Vol 1, Pt 1 Regulations* are to comply with the minimum requirements of *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements* and general structural requirements of Sections *Vol 1, Pt 6, Ch 3, 5 Shell envelope plating* to *Vol 1, Pt 6, Ch 3, 16 Masts*.

1.1.3 The basic structural scantlings of NS1 ships are to be determined in accordance with *Vol 1, Pt 6, Ch 3, 3 NS1 scantling determination* and supported where necessary by direct calculations.

1.1.4 The basic structural scantlings of NS2 and NS3 ships are to be determined in accordance with *Vol 1, Pt 6, Ch 3, 4 NS2 and NS3 scantling determination* and supported by direct calculations where necessary.

1.2 General

1.2.1 The formulae used in this Chapter are to be used in conjunction with the design loadings from *Vol 1, Pt 5 Environmental Loads* and design tools in *Vol 1, Pt 6, Ch 2 Design Tools* to determine the rule scantling requirements.

1.2.2 All references to longitudinal locations in the rules are to be taken as forward of the aft end of L_R unless otherwise stated, e.g. 0,75L_R is 75 per cent of L_R forward of the aft end of L_R

where

L_R is defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*

1.3 Direct calculations

1.3.1 The extent of direct calculation required will depend on the ship's structural configuration and operational requirements and is to be agreed between the designer, Owner, Naval Administration and Lloyd's Register (hereinafter referred to as 'LR') at an early stage in the plan approval process.

1.3.2 In addition, where the ship is of unusual design, form, proportion or has operational requirements such as very high speed, the scantlings will be specially considered and may require direct calculation.

1.4 Equivalents

1.4.1 LR will consider direct calculations for the derivation of scantlings as an alternative and equivalent to those derived by rule requirements in accordance with *Vol 1, Pt 3, Ch 1, 2 Direct calculations Vol 1, Pt 3, Ch 1, 2 Direct calculations* and *Vol 1, Pt 3, Ch 1, 3 Equivalents*.

■ *Section 2* Minimum structural requirements

2.1 General

2.1.1 The requirements of this Section, unless specified otherwise, are applicable to all ship types, NS1, NS2 and NS3.

2.1.2 The scantlings of plating and stiffeners determined from the Rule scantling requirements are not to be less than that given in *Table 3.2.1 Minimum structural requirements* for the ship type. Due consideration is to be given to the vessel type correction factor, ω, as defined in *Table 3.2.2 Vessel type correction factor (ω)*

2.1.3 In addition, where plating contributes to the global strength of the ship, the thickness is to be not less than that required to satisfy the global strength requirements detailed in *Vol 1, Pt 6, Ch 4 Hull Girder Strength*

2.2 Corrosion margin

2.2.1 The minimum thicknesses given in *Table 3.2.1 Minimum structural requirements* are based on the assumption that the correct coatings are used and a proper maintenance regime is employed such that there is negligible loss in strength due to corrosion. Where this is not the case the minimum thickness will be specially considered. For corrosion margins, *see Vol 1, Pt 6, Ch 6, 2.10 Corrosion margin*

Table 3.2.1 Minimum structural requirements

Item	Minimum Scantling		
Shell envelope			
Bottom shell and bilge plating	$\sqrt{k_{ms}}\left(0,4\sqrt{L_R}+2\right)$ mm	$\geq 5{,}0\omega$	
Side shell plating	$\sqrt{k_{ms}}\left(0,38\sqrt{L_R}+1,2\right)$ mm	$\geq 4{,}0\omega$	
Breadth of keel plate, if fitted	$7L_R+340$ mm	≥ 750	*See* Note 1
Keel plate thickness, if fitted	$\omega\sqrt{k_{ms}}\,1,35L_1^{0,45}$ mm		*See* Note 2
Breadth of stem plate	$7L_R+340$ mm	≥ 600	*See* Note 2
Stem plate thickness	$\omega\left(5+0,083L_2\right)\sqrt{k_{ms}}$ mm		
Bar keel area, if fitted	$\omega\,k_{ms}L_R^{1,1}$ cm^2		
Bar keel thickness, if fitted	$\omega\sqrt{k_{ms}}\left(0,6L_R+6\right)$ mm		*See* Note 2

Single bottom structure			
Centre girder web thickness	$\sqrt{k_{ms}}\left(\sqrt{L_R}+1\right)$ mm	≥ 4,0ω	
Side girder web thickness	$\sqrt{\left(k_{ms}L_R\right)}$ mm	≥ 3,5ω	
Floor web thickness	$\omega\sqrt{k_{ms}}\left(0,03L_R+3,5\right)$ mm	≥ 3,5ω	
Centreline girder face flat area	$\omega\,0,5L_Rk_{ms}$ cm^2		
Floor face flat area	$4,5Tk_{ms}\left(1-\frac{2,5}{B}\right)$ cm^2		*See* Note 3
Depth of floors, d_f	$35(1,6B+T)-75$ mm		
Double bottom structure			
Inner bottom plating thickness	$\sqrt{k_{ms}}\left(0,4\sqrt{L_R}+1,5\right)$ mm	≥ 4,0ω	
Centreline girder web thickness	$\sqrt{k_{ms}}\left(0,9\sqrt{L_R}+1\right)$ mm	≥ 4,0ω	
Side girder web thickness	$\sqrt{k_{ms}}\,0,72\sqrt{L_R}$ mm	≥ 3,5ω	
Floor web thickness	$\sqrt{k_{ms}}\left(0,03L_R+3,5\right)$ mm	≥ 3,5ω	
Depth of double bottom, d_{DB}	$28B+205\sqrt{T}$ mm	≥ 630	
Watertight bulkheads			
Plating thickness	$\omega\sqrt{k_{ms}}\left(0,33\sqrt{L_R}+1,0\right)$ mm	≥ 3,5ω	
Deep tank bulkheads			
Plating thickness	$\omega\sqrt{k_{ms}}\left(0,38\sqrt{L_R}+1,2\right)$ mm	≥ 4,0ω	
Deck structure			
Strength deck	$\omega\sqrt{k_{ms}}\left(0,38\sqrt{L_R}+1,2\right)$ mm	≥ 4,0ω	
Internal and lower decks	$\omega\sqrt{k_{ms}}\left(0,18\sqrt{L_R}+1,7\right)$ mm	≥ 3,0ω	
Exposed deck plating thickness, fwd of 0,75L_R	$\omega\sqrt{k_{ms}}\left(0,015L_R+5,5\right)$ mm	≥ 5,0ω	
Exposed deck plating thickness, aft of 0,75L_R	$\omega\sqrt{k_{ms}}\left(0,38\sqrt{L_R}+1,2\right)$ mm	≥ 4,0ω	
Superstructure and deckhouses			
Deck plating thickness	$\omega\sqrt{k_{ms}}\left(0,18\sqrt{L_R}+1,7\right)$ mm	≥ 3,0ω	
Side plating thickness	$\omega\sqrt{k_{ms}}\left(0,3\sqrt{L_R}+1\right)$ mm	≥ 3,0ω	
Front plating thickness, fwd of 0,75L_R	$\omega\sqrt{k_{ms}}\left(0,3\sqrt{L_R}+2\right)$ mm	≥ 5,0ω	
Front plating thickness, aft of 0,75L_R	$\omega\sqrt{k_{ms}}\left(0,25\sqrt{L_R}+2\right)$ mm	≥ 4,0ω	
Back plating thickness	$\omega\sqrt{k_{ms}}\left(0,25\sqrt{L_R}+2\right)$ mm	≥ 3,0ω	
Machinery casing plating thickness	$\omega\sqrt{k_{ms}}\left(0,25\sqrt{L_R}+2\right)$ mm	≥ 3,0ω	

Pillars		
Wall thickness of tubular pillars	$\omega \sqrt{k_{ms}}\, 0,05 d_p$ mm	$\geq 2,5\omega$
Wall thickness of rectangular pillars	$\omega \sqrt{k_{ms}}\, 0,05 b_p$ mm	$\geq 2,5\omega$
Plated mast structures which are not structurally effective		
Deck, side and back plating	3mm	
Front plating thickness, fwd of $0,75L_R$	5mm	
Front plating thickness, aft of $0,75L_R$	4mm	
Symbols		

L_1 = L_R but need not be taken greater than 190m

L_2 = L_R but need not be taken greater than 215m

ω = vessel type correction factor as determined from *Table 3.2.2 Vessel type correction factor (ω)*

k_{ms} = $635/(\sigma_o + \sigma_u)$

σ_o = specified minimum yield strength of the material, in N/mm^2

σ_u = specified minimum ultimate tensile strength of the material, in N/mm^2

b_p = minimum breadth of cross section of hollow rectangular pillar, in mm

d_p = outside diameter of tubular pillar, in mm

= L_R, B and T are defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*

Note 1. Maximum keel breadth 1800 mm.

Note 2. Not to be less than adjacent shell plate. Above the design waterline the bar keel may be the same as the adjacent shell.

Note 3. Face plate thickness not to be less than floor thickness.

Table 3.2.2 Vessel type correction factor (ω)

Vessel type	ω
Bottom structure of ships operating aground	1,2
NS1	1,1
NS2 and NS3	1,0

2.3 Impact consideration

2.3.1 Due consideration is to be given to the scantlings of all structures which may be subject to local impact loadings. For example decks in workshops. Impact testing may be required to be carried out at the discretion of LR to demonstrate the suitability of the proposed scantlings for a particular application.

2.4 Sheathing

2.4.1 Areas of shell and deck which are subject to additional wear by abrasion from, i.e. removal or stores routes, working areas, forefoot region, etc. are to be suitably protected by local reinforcement or sheathing. This sheathing may be of timber, rubber, steel, additional layers of reinforcement, etc. as appropriate. Details of such sheathing and the method of attachment are to be submitted for consideration.

2.4.2 The attachment of sheathing by mechanical means such as bolting or other methods is not to impair the watertight integrity of the ship. Through bolting of the hull is to be kept to a minimum and avoided where practicable. The design arrangements in way of any through bolting are to be such that damage to the sheathing will not impair the watertight integrity of the hull.

2.4.3 When decks that are not structurally effective or subject to significant inplane stresses are fitted with approved sheathing, the thickness derived may be reduced by 10 per cent for a 50 mm sheathing thickness, or five per cent for 25 mm, with intermediate values in proportion. The steel deck is to be coated with a suitable material in order to prevent corrosive action, and the sheathing or composition is to be effectively secured to the deck. Inside deckhouses the thickness may be reduced by a further 10 per cent.

2.5 Special considerations

2.5.1 Flight decks and structures in way of launcher ramps, gun platforms, etc. will be subject to special consideration.

2.5.2 The minimum plating thickness of ships intended for operation in ice conditions will be specially considered.

2.5.3 Ships with shock enhanced notation are not to be fitted with bar keels. Docking arrangements are to be specially considered.

2.5.4 For large or novel ships, the scantlings of the stern will be specially considered.

2.5.5 Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

2.6 Direct calculations

2.6.1 The thickness requirements derived from *Table 3.2.1 Minimum structural requirements* may be specially considered, where direct calculation procedures are adopted to demonstrate the suitability of the proposed alternative, e.g. shear buckling analysis may be performed on girder or floor webs.

■ *Section 3*
NS1 scantling determination

3.1 General

3.1.1 The scantlings for NS1 ships may be determined from the global and local requirements defined in this Section. In addition the general requirements of Sections *Vol 1, Pt 6, Ch 3, 5 Shell envelope plating* to *Vol 1, Pt 6, Ch 3, 15 Strengthening for wave impact loads above waterline* are to be complied with.

3.1.2 The scantlings given in this Section are based on the assumption that the correct coatings are used and a proper maintenance regime is employed such that there is negligible loss in strength due to corrosion. For corrosion margins, *see Vol 1, Pt 6, Ch 6, 2.10 Corrosion margin*.

3.2 Symbols

3.2.1 The symbols used in this Section are defined as follows:

F_B = local scantling reduction factor for hull members below the neutral axis, *see Vol 1, Pt 6, Ch 3, 3.6 Local reduction factors*

F_D = local scantling reduction factor for hull members above the neutral axis, *see Vol 1, Pt 6, Ch 3, 3.6 Local reduction factors*

I_{min} = minimum moment of inertia, of the hull midship section about the transverse neutral axis, in m^4

Z_D, Z_B = actual hull section moduli, in m^3, at strength deck and keel respectively, *see Vol 1, Pt 6, Ch 4, 2 Hull girder strength*

Z_{min} = minimum hull midship section modulus about the transverse neutral axis, in m^3

σ_p = permissible combined stress (still water plus wave), in N/mm^2, *see Vol 1, Pt 6, Ch 4, 2 Hull girder strength*

σ_o = yield strength of material in N/mm^2

σ_D, σB = maximum hull vertical bending stress at strength deck and keel respectively, in N/mm^2 determined from *Vol 1, Pt 6, Ch 4, 2 Hull girder strength*

k_L = longitudinal high strength steel factor, *see Vol 1, Pt 6, Ch 5, 2.1 Design criteria 2.1.2*

k_s = the local high strength steel factor, *see Vol 1, Pt 6, Ch 5, 2.1 Design criteria 2.1.1*

L_1 = L_R but need not be taken greater than 190 m

L_2 = L_R but need not be greater than 215 m

s = spacing of secondary stiffeners, in mm

S = spacing of primary members, in metres

ρ = relative density (specific gravity) of a liquid carried in a tank not to be taken less than 1,025

f = $\dfrac{1}{1+\left(\frac{s}{1000S}\right)^2}$ transverse framing aspect ratio correctionL_R is as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*

3.3 Hull girder strength

3.3.1 For all ships, the hull girder strength requirements of *Vol 1, Pt 6, Ch 4, 2 Hull girder strength* are to be complied with.

3.3.2 As required by *Vol 1, Pt 6, Ch 4, 2 Hull girder strength*, the hull girder bending and shear stresses for all longitudinally effective material is to be verified against the permissible stresses and the buckling requirements of *Vol 1, Pt 6, Ch 2, 3 Buckling*. In addition, the lateral and torsional stability of all effective longitudinals together with the web and flange buckling criteria are to be verified in accordance with *Vol 1, Pt 6, Ch 2, 3 Buckling*

3.3.3 In addition, the minimum requirements of *Vol 1, Pt 6, Ch 3, 3.4 Minimum hull section modulus* and *Vol 1, Pt 6, Ch 3, 3.5 Minimum hull moment of inertia* are to be satisfied.

3.4 Minimum hull section modulus

3.4.1 The hull midship section modulus about the transverse neutral axis, at the deck or the keel, is to be not less than:

$$Z_{min} = 0{,}95 k_L M_o \text{x} 10^{-5} \text{ m}^3$$

where

M_o is given in *Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments 3.3.1*

K_L is as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1*

3.5 Minimum hull moment of inertia

3.5.1 The hull midship section moment of inertia about the transverse neutral axis is to be not less than the following using the maximum total bending moment, sagging or hogging:

$$\boldsymbol{I}_{min} = 3{,}0 L_R M_R / 175 \times 10^{-5} \text{ m}^4$$

where

M_R = design bending moment, sagging (negative) and hogging (positive), in kN m, to be taken negative or positive according to the convention given in *Vol 1, Pt 5, Ch 4, 3.10 Hull girder design loads*

3.6 Local reduction factors

3.6.1 Where the maximum hull vertical bending stress at deck or keel is less than the permissible combined stress, σ_p, reductions in local scantlings within 0,3L_R to 0,7L_R may be permitted. The reduction factors are defined as follows:

For hull members above the neutral axis

$$F_D = \sigma_D/\sigma_p$$

For hull members below the neutral axis

$$F_B = \sigma_B/\sigma_p$$

In general the values of σ_D and σ_B to be used are the greater of the sagging or hogging stresses, and F_D and F_B are not to be taken less than 0,67 for plating and 0,75 for longitudinal stiffeners. σ_B, σ_D and σ_p are defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1*

3.6.2 Where higher tensile steel is used in the hull structure, the values of F_D and F_B for the mild steel part are to be taken as not less than z/z_M

where

z = vertical distance from the hull transverse neutral axis to the position considered, in metres

z_M = vertical distance, in metres, from the hull transverse neutral axis to the minimum limit of higher tensile steel, above or below the neutral axis as appropriate.

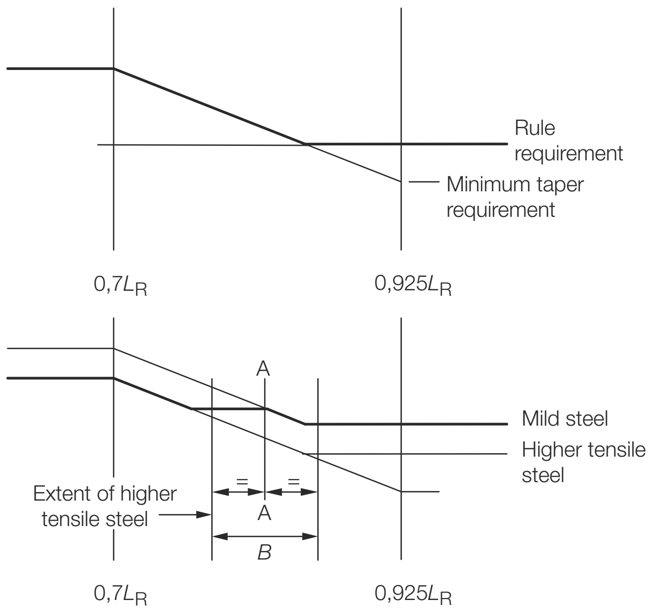
3.7 Taper requirements for hull envelope

3.7.1 The scantlings determined at amidships are to be maintained between 0,3L_R and 0,7L_R. Outside of this region and forward of 0,075L_R and aft of 0,925L_R the scantling requirements for the following structural items are to be determined by linear interpolation between the midship section and the forward or after ends as appropriate, *see Figure 3.3.1 Taper requirements*:

- Strength deck plating.
- Deck longitudinals.
- Shell envelope.

3.7.2 The taper requirement does not apply to ships where there are large openings in the decks such that the torsional rigidity of the hull is significantly reduced.

3.7.3 The thickness may need to be increased above the taper thickness by military features, special features or other requirements such as bottom slamming or bow flare impact.



A–A = centre of aftermost mild steel plate
B = length of aftermost mild steel plate

Figure 3.3.1 Taper requirements

3.7.4 The formulae for the taper values are based on the assumption that the yield values of steel is the same at amidships and ends. Where higher tensile steel is used in the midship region and mild steel at the ends, the taper values should be calculated for both yield values of steel. In way of the transition from higher tensile to mild steel, the thickness may be determined in accordance with *Figure 3.3.1 Taper requirements* The aft end thickness is to be tapered in a similar manner.

3.7.5 Where the higher tensile steel longitudinals extend beyond the point of transition from higher tensile to mild steel plating, the modulus of the composite section is to be greater than the required mild steel value at the deck plate flange, and k_L times the mild steel value at the higher tensile flange.

3.8 Grouped stiffeners

3.8.1 Where stiffeners are arranged in groups of the same scantling, the section modulus requirement of each group is to be based on the greater of the following:

(a) the mean value of the section modulus required for individual stiffeners within the group;

(b) 90 per cent of the maximum section modulus required for individual stiffeners within the group.

3.9 Shell envelope plating

3.9.1 Shell envelope plating for both longitudinally and transversely framed ships is to comply with the requirements of *Table 3.3.1 Shell envelope plating*

Table 3.3.1 Shell envelope plating

<table>
<tr><td rowspan="2">Location</td><td colspan="2">Minimum thickness, in mm, see also Vol 1, Pt 6, Ch 3, 5.3 Sheerstrake 5.3.1</td></tr>
<tr><td>Longitudinal framing</td><td>Transverse framing</td></tr>
<tr><td>(1) Bottom plating and bilge where framed 0,3L_R to 0,7L_R(see Notes 3, 4 and 5)</td><td>The greater of the following:
(a) $t = 9,0 s_1 \left(0,043 L_1 + 10\right)\sqrt{\frac{F_B}{k_L}} \times 10^{-4}$
(b) $t = 4,7 s_1 \sqrt{\frac{h_{T2} k_s}{1,8 - F_B}} \times 10^{-3}$</td><td>The greater of the following:
(a) $t = 0,001 s_1 f\left(0,056 L_1 + 16,7\right)\sqrt{\frac{F_B}{k_L}}$ (see Note 4)
(b) $t = 5,7 s_1 \sqrt{\frac{h_{T2} k_s}{1,8 - F_B}} \times 10^{-3}$</td></tr>
<tr><td>(2) Bottom plating and bilge fwd of 0,925L_R (see Note 2) aft of 0,075L_R</td><td colspan="2">$t = \left(6,0 + 0,03 L_R\right)\sqrt{\frac{k_s s_1}{s_b}}$</td></tr>
<tr><td rowspan="3">(3) Side shell clear of sheerstrake 0,3L_R to 0,7L_R(see Notes 1 and 5)</td><td>(a) Above $\frac{D}{2}$ from base: The greater of the following:(i) $t = 9,0 s_1 \left(0,059 L_1 + 7\right)\sqrt{\frac{F_D}{k_L}} \times 10^{-4}$
(ii) $t = 3,8 s_1 \sqrt{h_{T1} k_s} \times 10^{-3}$</td><td>(a) Above $\frac{D}{4}$ from the gunwale: The greater of the following:(i) $t = 0,00085 s_1 f\left(0,083 L_1 + 10\right)\sqrt{\frac{F_D}{k_L}}$
(ii) $t = 3,8 s_1 \sqrt{h_{T1} k_s} \times 10^{-3}$</td></tr>
<tr><td>(b) At upper turn of bilge:The greater of the following:(i) $t = 9,0 s_1 \left(0,059 L_1 + 7\right)\sqrt{\frac{F_B}{k_L}} \times 10^{-4}$
(ii) $t = 4,9 s_1 \sqrt{\frac{h_{T2} k_s}{2 - F_B}} \times 10^{-3}$</td><td>(b) Within $\frac{D}{4}$ from the mid-depth: The greater of the following:(i)
$t = 9,0 s_1 \left(0,059 L_1 + 7\right)\sqrt{\frac{F_M}{k_L}} \times 10^{-4}$ (ii)
$t = 4,6 s_1 \sqrt{h_{T1} k_s} \times 10^{-3}$</td></tr>
<tr><td>(c) Between upper turn of bilge and $\frac{D}{2}$ from base:
The greater of the following:(i) t from (b)(i) (ii) t from interpolation from (a)(ii) and (b)(ii)</td><td>(c) Within $\frac{D}{4}$ from base (excluding bilge plating) see Note 1 The greater of the following:(i)
$t = 0,00085 s_1 f\left(0,083 L_1 + 10\right)\sqrt{\frac{F_B}{k_L}}$ (ii)
$t = 5,7 s_1 \sqrt{\frac{h_{T2} k_s}{1,8 - F_B}} \times 10^{-3}$</td></tr>
<tr><td>(4) Side shellfwd of 0,925L_R aft of 0,075L_R</td><td colspan="2">$t = \left(6,0 + 0,03 L_R\right)\sqrt{\frac{k_s s_1}{s_b}}$</td></tr>
<tr><td>(5) Sheerstrake</td><td colspan="2">$0,00075 s_1 \sqrt{L_R k_s} + 1,5$
but not less than the thickness of the adjacent side plating.</td></tr>
<tr><td colspan="3">Symbols</td></tr>
</table>

= F_B, F_D are as defined in *Vol 1, Pt 6, Ch 3, 3.6 Local reduction factors* = L_R, D, T are as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars* = L_1, L_2, ρ, s, S, f, k_L, k_s are as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1* C_{WL} = a wave head in metres = $0{,}0771 L_R e^{-0,0044 L_R}$ = Where L_R > 227 m, C_{WL} is not to be taken less that 6,446 m h_{T1} = $T + C_{WL}$, in metres but need not be taken greater than 1,36T m h_{T2} = $(T + 0{,}5C_{WL})$, in metres but need not be taken greater than 1,2T m	s_1 = s, but is not to be taken less than s_b s_b = 600mm fwd of $0,95L_R$ = 700mm 0, 95LR to $0,7L_R$ = 700mm 0, 7LR to $0,05L_R$ = 600mm aft of $0,05L_R$ F_M = the greater of F_B amd F_D e = base of natural logirithms, 2,7183

Note 1. Outside the vertical extent of higher tensile steel as defined in *Vol 1, Pt 6, Ch 2, 1.6 Higher tensile steel 1.6.3* the value of k_L may be taken as 1,0.

Note 2. *See also Vol 1, Pt 6, Ch 3, 14 Strengthening for bottom slamming* and *Vol 1, Pt 6, Ch 3, 15 Strengthening for wave impact loads above waterline* for requirements for bottom slamming and bow flare impact.

Note 3. For keel plate thickness and breadth, *see Table 3.2.1 Minimum structural requirements*.

Note 4. Unframed bilge plating will be specially considered.

Note 5. Shell envelope plating from 0,075L_R to 0,3L_R and 0,7L_R to 0,925L_R is to be determined by assuming a linear taper from the midship value given by (1) or (3) as appropriate to $t = (6{,}0 + 0{,}03L_R)\sqrt{k_s}$ at 0,075L_R and 0,925L_R. The plating thickness determined is not to be less than the value given by (2) or (4) as appropriate. *See also Vol 1, Pt 6, Ch 3, 3.7 Taper requirements for hull envelope*.

3.9.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*

3.9.3 Additional requirements for shell envelope plating are indicated in *Vol 1, Pt 6, Ch 3, 5 Shell envelope plating*.

3.10 Shell envelope framing

3.10.1 Shell envelope framing for both longitudinally and transversely framed ships is to comply with the requirements of *Table 3.3.2 Shell envelope framing (0,2L R to 0,8L R)* and *Table 3.3.3 Shell envelope framing forward and aft*

Table 3.3.2 Shell envelope framing (0,2L_R to 0,8L_R)

Longitudinal framing	Modulus, in cm^3
(1) Side longitudinals in way of dry spaces, including double skin construction *(see* Note 1)	The lesser of the following: (a) $Z = 0{,}05\, s k_s h_{T1} l_e^2 F_s F_1$ (b) Z from (3)(a) evaluated using s and l_e for the longitudinal under consideration and the remaining parameters evaluated at the base line
(2) Side longitudinals in way of wet spaces or deep tanks	The greater of the following: (a) Z as from (1) (b) As required by *Table 3.3.5 Watertight and deep tank bulkhead and deck scantlings* for deep tanks, using h_{T3} instead of h_4, but need not exceed Z from (3)(b) evaluated using l_{e1}, s and l_e for the longitudinal under consideration and the remaining parameters evaluated at the base line

(3) Bottom and bilge longitudinals	The greater of the following: (a) $Z = (0{,}002\, l_{e1} + 0{,}042)\, s\, k_s\, h_{T2}\, l_e^2\, F_s\, F_1$ (b) $Z = (0{,}002\, l_{e1} + 0{,}042)\, s\, k_s\, h_{T3}\, l_e^2\, F_s\, F_1$	
Transverse framing	Modulus, in cm^3	Inertia, in cm^4
(4) Side frames in dry spaces	The greater of the following: (a) $Z = C\, s\, k_s\, h_{T1}\, H^2 \times 10^{-3}$ (b) $Z = 8{,}2 s\, k_s\, D_1 \times 10^{-3}$	$I = \frac{3,2}{k_s}$ H Z
(5) Side frames in way of wet spaces or deep tanks	The greater of the following: (a) 1,15 x Z from (4) (b) $Z = 6s\, k_s\, h\, H^2 \times 10^{-3}$	$I = \frac{3,2}{k_s}$ H Z
(6) Frames supporting hatch end beams or deck transverses (*see* Note 3)	The greater of the following: (a) Z from (4) (b) $Z = 2{,}2(0{,}2\, l_s^2 + H^2) k_s\, S\, H_g$	$I = \frac{3,2}{k_s}$ H Z
(7) Bottom transverse frames (*see* Note 4)	$Z = 2s\, k_s\, T\, l_e \times 10^{-2}$	—
Symbols		

ρ, L_1, L_2, s, k_s, S are as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1*

L_R, D, T are as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*

C_{WL} is as defined in *Table 3.3.1 Shell envelope plating*

F_B, F_D are as defined in *Vol 1, Pt 6, Ch 3, 3.6 Local reduction factors*

l_e = are as defined in *Vol 1, Pt 6, Ch 2, 2.6 Determination of span length*, but is not to be taken less than 1,5 m except in way of the centre girder brackets required by *Vol 1, Pt 6, Ch 3, 8.5 Bracket floors*3 where a minimum span of 1,25 m may be used

l_{e1} = l_e in metres, but is not to be taken less than 2,5 m and need not be taken greater than 5,0 m

F_s is a fatigue factor for side longitudinals defined in *Table 3.3.3 Shell envelope framing forward and aft*

$$C_1 = \left.\begin{aligned} &\frac{60}{225 - 165F_D} \text{ at deck} \\ &= 1{,}0 \text{ at } \frac{D}{2} \\ &= \frac{75}{225 - 150F_B} \text{ at base line} \end{aligned}\right\} \text{Intermediate values by interpolation}$$

$$F_1 = \left.\begin{aligned} &\frac{DC_1}{4D + 20h_5} \text{ for side longitudnals above } \frac{D}{2} \\ &= \frac{DC_1}{25D + 20h_5} \text{ for side longitudnals below } \frac{D}{2} \end{aligned}\right\} \text{minimum } F_1 = 0{,}14$$

and bottom longitudinals

where

z = height above base, in metres

f_{cw} = 0,5 at base line

f_{cw} = 1,0 at T

f_{cw} = 0 at 1,6T and above

(f_{cw} Intermediate values by interpolation)

H_9 = weather head, h_1, or stores head, h_2, in metres, as defined in *Table 3.3.7 Deck longitudinals (longitudinal framing)* whichever is applicable

D_1 = 1,6T but not less than 10 or greater then 16 (*see* Note 1)

H = vertical framing depth in m l, but not less than 2,5 m, *see* Note 2

h_{T1} = $(T - z + f_{cw} C_{WL}) F_\lambda$ below T

= $f_{cw} C_{WL} F_\lambda$ above T but not less than the greater of $F_\lambda L_1/70$ or 1,2 m

h_{T2} = $(T + 0{,}5C_{WL}) F_\lambda$

= h_{T1} and h_{T2} need not exceed $(1{,}6T - z + D_1/8)$ below 1,6T and $(z - 1{,}6T + D_1/8)$ above 1,6T

h_{T3} = $0{,}9h_4 - 0{,}25T$, in metres, at the base line

= $0{,}9h_4$, in metres, at and above $T/4$ from the base line, intermediate values by linear interpolation

h_4 = load head required by *Table 3.3.5 Watertight and deep tank bulkhead and deck scantlings* for deep tanks

h_5 = measured from the mid length of the stiffener to the strength deck at side

h = h_4 or h_5 whichever is greater

F_λ = 1,0 for $L_R \leq 200$ m

= $[1{,}0 + 0{,}0023(L_R - 200)]$ for $L_R > 200$ m

C = end connection factor

= 3,1 where two Rule standard brackets are fitted

= $3{,}1\,(1{,}8 - 0{,}8\, l_a / l_b)$ where one Rule standard bracket and one reduced bracket fitted

= $3{,}1\,(2{,}15 - 1{,}15\, l_{am} / l_b)$ where two reduced brackets are fitted

= 5,5 where one Rule standard bracket is fitted

= $5{,}5\,(1{,}2 - 0{,}2\, l_a / l_b)$ where one reduced bracket is fitted

= 6,4 where no bracket is fittedThe requirements for frames where brackets larger than Rule standard are fitted will be specially considered

l_a = equivalent arm length, in mm, as derived from *Vol 1, Pt 6, Ch 6, 5.4 Scantlings of end brackets 5.4.5*

l_b = as defined in *Vol 1, Pt 6, Ch 6, 5.4 Scantlings of end brackets 5.4.5*

l_{am} = mean equivalent arm length, in mm, for both brackets l_s = span of supported beam or transverse in metres	
Note 1. The scantlings of members above D/2 may require special consideration on the basis of structural configuration and the distribution of bending stress at the section concerned. Note 2. Where frames are inclined at more than 15° to the vertical, H, is to be measured along a chord between span points of the frame. Note 3. If the modulus obtained from (6) for frames under deck transverses exceeds that obtained from (4) and (5), the intermediate frames may be reduced provided that the combined modulus is maintained and the reduction in any intermediate frame is not greater than 35 per cent. The reduced modulus is to be not less than that given by (4)(b). Note 4. For single bottom structure a plate floor is to be fitted at every frame.	

Table 3.3.3 Shell envelope framing forward and aft

Location	Modulus, in cm^3	
Longitudinal framing		
(1) Side longitudinals in way of dry spaces including double skin construction *(see* Note 3) (a) Forward of the collision bulkhead (b) Aft of the aft peak bulk head (c) Between the collision bulkhead and 0,8L and between aft peak bulkhead and 0,2L	Z = $0{,}0065 s\, k_s\, h_{T1}\, l_e^2\, F_s$ but not less than $Z = 0{,}007 s\, k_s\, l_e^2\,(0{,}6 + 0{,}167 D_2)$ Z = $0{,}008 s\, k_s\, h_{T1}\, l_e^2\, F_s$ but not less than $Z = 0{,}007 s\, k_s\, l_e^2\,(0{,}6 + 0{,}167 D_2)$ Z = $0{,}0065 s\, k_s\, h_{T1}\, l_e^2\, F_s$ or as required in the midship region whichever is the greater, but not less than $Z = 0{,}007 s\, k_s\, l_e^2\,(0{,}6 + 0{,}167 D_2)$	
(2) Side longitudinals in way of double skin or deep tanks	As required in the midship region	
(3) Bottom and bilge longitudinals (*see* Note 4)	As required in the midship region	
Transverse framing	Inertia cm^4	
(4) Side frames fwd of collision bulkhead and aft of aft peak bulkhead	The greater of (a) $Z = 1{,}85 s\, k_s\, T\, D_2\, S_1 \times 10^{-3}$ (b) $Z = 0{,}007 s\, k_s\, l_e^2\,(0{,}6 + 0{,}167 D_2)$	$I = f_1\, S_1\, Z / k_s$
(5) All other frames in dry spaces forward of 0,8L and aft 0,2L (*see* Note 2)	The greater of the following (a) $Z = C\, s\, k_s\, h_{T1}\, H^2 \times 10^{-3}$ (b) $Z = 8{,}2 s\, k_s\, D_2 \times 10^{-3}$ (c) $Z = 0{,}007 s\, k_s\, l_e^2\,(0{,}6 + 0{,}167 D_2)$	$I = f_1\, S_1\, Z / k_s$
(6) Panting stringer	Web depth, d_w, same depth as framesWeb thickness, $t = 5 + 0{,}025 L_2$ mmFace area, $A = k_s\, S_2 (H + 1)$ cm^2	
(7) Main and 'tween deck frames elsewhere	As required in the midship region	
Symbols		

L_1, L_2, s, k_s are as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1* L_R, D, T are as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars* C_{WL} as defined in *Table 3.3.1 Shell envelope plating* F_λ as defined in *Table 3.3.2 Shell envelope framing (0,2L R to 0,8L R)* l_e = as defined in *Vol 1, Pt 6, Ch 2, 2.6 Determination of span length* but is to be taken not less than 1,5 m D_2 = $T + H_b$ metres, where H_b is the minimum bow height, in metres, obtained from *Vol 1, Pt 3, Ch 2, 5.3 Minimum bow height and extent of forecastle* H = vertical framing depth, in metres, of sideframes, but is to be taken not less than 2,5 m (*see* Note 1) S_1 = vertical spacing of peak stringers or height of lower deck above the peak, in metres S_2 = vertical spacing of panting stringers, in metres C = end connection factor, *see* Table 3.3.2 f_L = 1,32 aft of 0,15L_R = 1,0 from 0,2L_R to 0,8L_R = 1,71 fwd of 0,85L_RIntermediate positions by interpolation z = height above baseline in metres	h_{T1} = $(T - z + f_L f_{cw} C_{WL}) F_\lambda$ below T = $f_L f_{cw} C_{WL} F_\lambda$ above T but not less than $f_L F_\lambda L_1/70$ f_{cw} = 0,5 at baseline = 1,0 at 0,65D_2 and above Intermediate positions by interpolation (*see* Note 5) f_1 = 3,5 forward and 3,2 aft F_s = fatigue factor for side longitudinals for built symmetric sections, flat bars, bulbs and T bars = 1,05 at keel, 1,1 at T, 1,0 at 1,6T and above for angle bars = $0,5\left(1 + \frac{1,1}{k_s}\right)$ at keel = $\frac{1,1}{k_s}$ at $\frac{D}{2}$ = 1,0 at 1,6 T and abovebuilt asymmetric sections will be specially considered. Intermediate values by linear interpolation

Note 1. Where frames are inclined at more than 15° to the vertical, H is to be measured along a chord between the span points of the frame.

Note 2. The modulus for these members need not exceed that derived from (4) using H in place of S_1.

Note 3. Where struts are fitted midway between transverses in double skin construction, the modulus of the side longitudinals may be reduced by 50k per cent from that obtained for locations (2) and (3) as applicable.

Note 4. Shell framing is also to comply with the requirements for bottom slamming and bow flare impact in *Vol 1, Pt 6, Ch 3, 14 Strengthening for bottom slamming* and *Vol 1, Pt 6, Ch 3, 15 Strengthening for wave impact loads above waterline* respectively.

Note 5. For ships where $T > 0,65D_1$, the distribution of f_{cw} will be specially considered.

3.10.2 Shell envelope primary structure for both longitudinally and transversely framed ships is to comply with the requirements of *Table 3.3.4 Shell envelope primary structure*.

Table 3.3.4 Shell envelope primary structure

Item and location	Modulus, in cm^3	Inertia, in cm^4
Longitudinal framing system:		
(1) Side transverse web frames in dry spaces	$Z = 9,0 k_s S h_{T1} l_e^2$	—

(2) Side transverse web frames in deep tanks (a) midships (b) aft of 0,2 L_R (c) fwd of 0,8 L_R	$Z = 9,4 k_s S h_4 l_e^2$ $Z = 11,0 k_s S h_4 l_e^2$ $Z = 11,0 k_s S h_4 l_e^2 f_\gamma$ or as (1) above, whichever is the greater	$I = \frac{2,5}{k_s} l_e Z$
(3) Side transverses in dry spaces above 1,6T (*see* Note 2),	$Z = C_2 k_s S T H \sqrt{D}$	—
Transverse framing system:		
(4) = Side stringers in dry spaces	$Z = 7,0 k_s S h_{T1} l_e^2$	—
= (5) Side stringers in deep tanks	$Z = 9,4 k_s S h_4 l_e^2$ or as (5) above, whichever is the greater	$I = \frac{2,5}{k_s} l_e Z$
(6) Web frames in dry spaces above 1,6T (*see* Note 2)	$Z = C_3 k_s S T H D$	—
(7) Web frames supporting side stringers	Z determined from calculation based on following assumptions: (a) = fixed ends (b) = point loadings (c) = head $f_\gamma h_4$ or $f_\gamma h_{T1}$ as applicable (d) = bending stress $\frac{100}{k_s}$ N/mm^2 (e) = shear stress $\frac{90}{k_s}$ N/mm^2	$I = \frac{2,5}{k_s} l_e Z$
Symbols		

= ρ, s, S, k_s are as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1*

= D, T, L_R are as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*

h_4 = tank head, in metres, as defined in *Table 3.3.6 Deck plating*

L = load head, in metres, measured from mid-point of span to upper deck at side amidships

l_e = effective length of stiffening member, in metres, *see Vol 1, Pt 6, Ch 2, 2.6 Determination of span length*

h_{T1} = as defined in *Table 3.3.3 Shell envelope framing forward and aft*

f_γ = measured at midspan of member fwd of 0,8L_R
= 1,0 at base line
= B_f at 0,6D above base
= 0,5 (B_f – 1) + 1 at D above base
= 1,0 at any depth aft of 0,8L_R

Intermediate values by linear interpolation

B_f = *see Figure 3.3.2 Bow fullness factor* for frame members fwd of 0,8L_R
= 1 for framing members aft of 0,8L_R

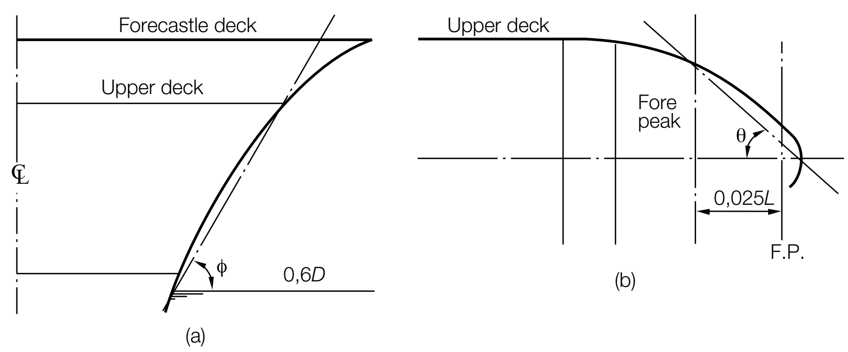
$C_2 C_3$ = from *Figure 3.3.4 Framing Factors C2 (C3)*

H = vertical height between decks in metres

Note 1. For primary structure in way of machinery spaces and also forward of 0,8L_R the minimum web depth is not to be less than 2,5 times the depth of adjacent frames or longitudinals as appropriate. Stringers forward of 0,8L_R may be 2,2 times the depth of the adjacent stiffener.

Note 2. For stringers and webs in fore peak tanks or deep tanks, *see Vol 1, Pt 3, Ch 2, 3.8 Deep tank structure*.

Note 3. The breadths and effective length should be measured along the line of the shell.



Conditions for ϕ

1. ϕ to be deduced at 0,975L_R
2. Aft of fore peak tank ϕ is to be deduced at section being considered
3. For ships with a bulbous bow the angle ϕ is to be measured from the narrowest point of the bow between 0,6D from base and upper deck

Bow fullness factor
B_f = 2,45 cos ϕ tan θ
but not to be taken less than 1,0

Figure 3.3.2 Bow fullness factor

3.10.3 Additional requirements for shell envelope framing are indicated in *Vol 1, Pt 6, Ch 3, 6 Shell envelope framing*

3.11 Watertight bulkheads and deep tanks

3.11.1 Watertight bulkhead and deep tank scantlings are to comply with the requirements of *Table 3.3.5 Watertight and deep tank bulkhead and deck scantlings* Factors for the stiffener end connection type are given in *Figure 3.3.3 Bulkhead end constraint factors*

Table 3.3.5 Watertight and deep tank bulkhead and deck scantlings

Item and requirement	Watertight bulkheads and decks	Deep tank bulkheads, decks and collision bulkheads
Plating		
(1) Plating thickness for plane, symmetrically corrugated and double plate bulkheads	t = 0,004s β $\sqrt{h_4 k_s}$ mm but not less than 5,0 mm	t = 0,0057s β $\sqrt{h_4 k_s}$ mm but not less than 6,0 mm
Secondary stiffening		
(2) Modulus of rolled and built stiffeners, swedges, double plate bulkheads and symmetrical corrugations	$Z = \dfrac{s k_s h_4 l_e^2}{71 f_s(\omega_1 + \omega_2 + 2)}$ cm^3	$Z = \dfrac{s k_s h_4 l_e^2}{22 f_s(\omega_1 + \omega_2 + 2)}$ cm^3
(3) Inertia of rolled and built stiffeners and swedges	—	$I = \dfrac{2,3}{k_s} l_e Z$ cm^4
Primary stiffening		
(4) Stringers or webs supporting vertical or horizontal stiffening:		
(a) = Modulus	Z = 5,0$k_s h_4 S l_e^2$ cm^3	Z = 10,5$k_s h_4 S l_e^2$ cm^3
(b) = Inertia	—	$I = \dfrac{2,5}{k_s} l_e Z$ cm^4
Symbols		

= s, S, k_s as defined in *Table 3.2.1 Minimum structural requirements*

l_e = effective length of stiffening member in metres and for bulkhead stiffeners, *see Figure 3.3.3 Bulkhead end constraint factors*

f_s = 1,4 for rolled or built sections and double plate bulkheads

= 1,6 for flat bars

= 1,1 for symmetrical corrugations of deep tank bulkheads

= 1,0 for symmetrical corrugations of watertight bulkheads

h_4 = 0,1P_{bhp} for deep tank and watertight bulkhead plating

= 0,1P_{bhs} for deep tank and watertight stiffening

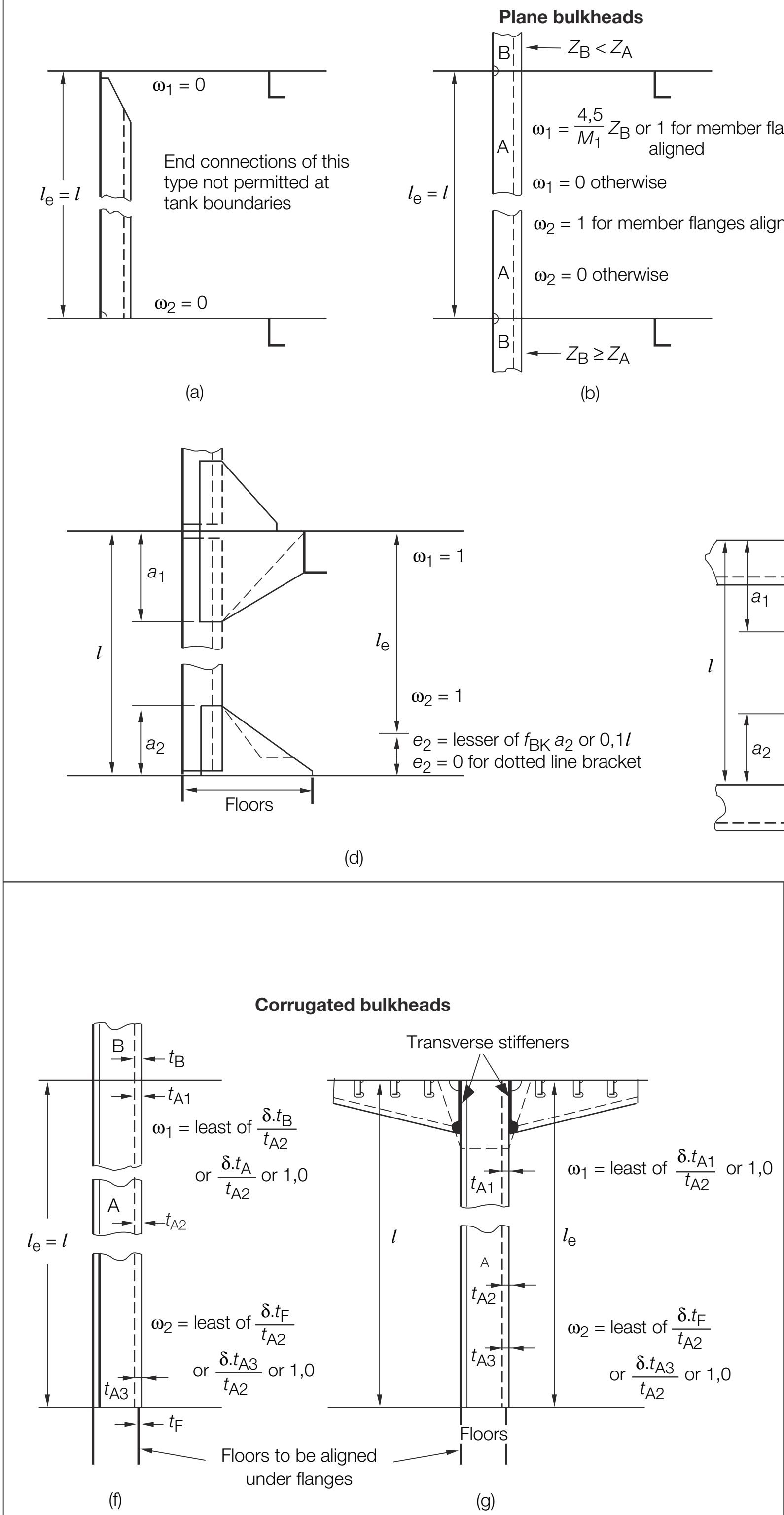
= P_{bhp} and P_{bhs} are the bulkhead design pressures as defined in *Vol 1, Pt 5, Ch 3, 5.8 Design pressures for watertight and deep tank bulkheads and boundaries*

= ω_1 and ω_2 are bulkhead end constraint factors, *see Figure 3.3.3 Bulkhead end constraint factors*

β = aspect ratio correction factor, *see Vol 1, Pt 6, Ch 2, 2.5 Aspect ratio correction 2.5.1*

Note 1. In no case are the scantlings of deep tank bulkheads to be less than the requirements for watertight bulkheads where watertight bulkheads are required by *Vol 1, Pt 3, Ch 2, 4 Bulkhead arrangements*.

Note 2. Corrugated bulkheads are to comply with the requirements of *Vol 1, Pt 6, Ch 2, 2.3 Section properties*. Both the plate panels and section inertia and modulus requirements are to be assessed.



l, k_s, s are as defined in Ch 2,1.3.1

B = adjacent member

A = member under consideration

Z_A, Z_B = modulus of member in cm^3

M_1 = $\dfrac{h_4\, s\, l_e^2}{51}$ for watertight and magazine bulkheads

= $\dfrac{h_4\, s\, l_e^2}{28}$ for deep tank bulkheads

a = bracket length, in metres, *see* Ch 2,3.2

t_A, t_B = thickness of member, in mm

d_A, d_B = web depth of member, in mm

l_e = effective length = $(l - e_1 - e_2)$, in metres

f_{BK} = bracket stiffening factor
1,0 for flanged and fixed ends
0,7 for flanged and sniped ends
0,5 for unflanged ends

d = 1,0 or $0{,}932 \dfrac{k_s}{\xi}$ for watertight and magazine bulkheads

ξ = 1,0 for full continuity of bulkheads

= $\dfrac{\eta t_m \sqrt{k_s}}{b} + 0{,}333$ but not less than 1,0 nor greater than 1,333 where there is not full continuity

ν = 50 for welded sections
= 60 for cold formed sections

Fig. 3.3.3 Bulkhead end constraint factors

Figure 3.3.3 Bulkhead end constraint factors

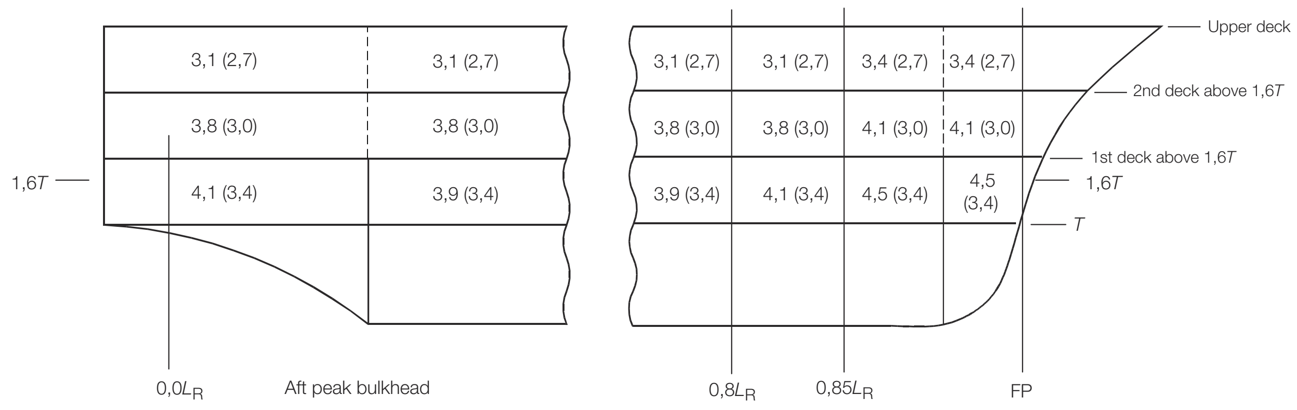


Figure 3.3.4 Framing Factors C_2 (C_3)

3.11.2 The thickness of the watertight bulkhead and deep tank plating is in no case to be less than the appropriate minimum requirements given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*.

3.11.3 Additional requirements for watertight bulkhead and deep tank scantlings are indicated in *Vol 1, Pt 3, Ch 2, 4 Bulkhead arrangements* and *Vol 1, Pt 3, Ch 2, 3 Main hull structure* respectively.

3.12 Deck structures

3.12.1 Deck plating for both longitudinally and transversely framed ships is to comply with the requirements of *Table 3.3.6 Deck plating*

Table 3.3.6 Deck plating

Location	Minimum thickness, in mm, *see also Vol 1, Pt 6, Ch 3, 2.2 Corrosion margin*	
	Longitudinal framing	Transverse framing
(1) Strength deck 0,3L_R to 0,7L_R (*see* Notes 1, 2 and 6)	The greater of the following:(a) $t = 9,0 s_1 \left(0,059 L_1 + 7\right) \sqrt{\frac{F_D}{k_L}} \times 10^{-4}$ (b) $t = \left(7,4 s_1 \sqrt{L_R k_s} \times 10^{-4}\right) + 1,5$	The greater of the following:(a) $t = s_1 f \left(0,083 L_1 + 10\right) \sqrt{\frac{F_D}{k_L}} \times 10^{-4}$ (b) $t = 0,001 s_1 \sqrt{L_R k_s} + 2,0$
(2) Weather deck and exposed decks (*see* Note 2)	$t = \left(7,4 s_1 \sqrt{L_R k_s} \times 10^{-4}\right) + 1,5$	$t = \left(7,4 s_1 \sqrt{L_R k_s} \times 10^{-4}\right) + 1,0$
(3) Lower decks (a) effective (continuous) (b) non effective	$t = 0,011 s_1 \sqrt{k_s}$ $t = 0,009 s_1 \sqrt{k_s}$	
(4) Strength deck (a) forward of 0,925L_R and aft of 0,075L_R (b) Lower decks	$t = \left(5,0 + 0,018 L_R\right) \sqrt{\frac{k_s s_1}{s_b}}$ $t = 0,009 s_1 \sqrt{k_s}$	
(5) Plating forming the upper flange of underdeck girders	Clear of deck openings, $t = \sqrt{\frac{A_f}{2,2 k_s}}$ In way of deck openings, $t = 1,1 \sqrt{\frac{A_f}{2,2 k_s}}$ Minimum breadth, b = 760 mm	

Symbols	
s, S, L_1, ρ, k_L, k_s, f are as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1*	s_b = As defined in *Table 3.3.1 Shell envelope plating*, except of aft of 0,05L_R equal to 850 mm
L_R as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*	F_D = as defined in *Vol 1, Pt 6, Ch 3, 3.6 Local reduction factors*
s_1 as defined in *Table 3.3.1 Shell envelope plating* breadth of increased plating, in mm	A_f = girder face area in cm^2

Note 1. The thickness derived in accordance with (1) is also to satisfy the buckling requirements of *Vol 1, Pt 6, Ch 2, 3 Buckling* and minimum thickness requirements.

Note 2. The deck thickness is to be not less than the basic end deck thickness as given in (4).

Note 3. Where a deck loading exceeds 43,2 kN/m^2, the thickness of plating will be specially considered.

Note 4. The exposed deck taper thickness is to extend into a forecastle or poop for at least one third of the beam, B, from the superstructure end bulkhead.

Note 5. For decks forming the boundary of a tank the plating thickness is to be 1,0 mm in excess of the requirements in *Table 3.3.5 Watertight and deep tank bulkhead and deck scantlings* for deep tanks.

Note 6. Strength deck plating from 0,075L_R to 0,3L_R and 0,7L_R to 0,925L_R is to be determined by assuming a linear taper from the midship value (1) to $t = (5,0 + 0,018 L_R) \sqrt{k_s}$ at 0,075L_R and 0,925L_R. The plating thickness determined is not to be less than (4). The total area of strength deck plating at 0,075L_R and 0,925L_R is not to be less than 30 per cent of the midship value, *see Vol 1, Pt 6, Ch 3, 3.7 Taper requirements for hull envelope*.

3.12.2 Deck framing for both longitudinally and transversely framed ships is to comply with the requirements of *Table 3.3.7 Deck longitudinals (longitudinal framing)* and for transversely framed ships *Table 3.3.8 Deck beams (transverse framing)*

Table 3.3.7 Deck longitudinals (longitudinal framing)

Location		Modulus, in cm^3
(1) Strength deck $0{,}3L_R$ to $0{,}7L_R$		$Z = 0{,}039\, s\, k_s\, h_{T1}\, l_e^2\, F_1$
(2) Weather deck and exposed deck		
(a) $0{,}075L_R$ to $0{,}8L_R$		$Z = s\, k_s\, (360h_1 + 0{,}0045\, (l_e L_2)^2) \times 10^{-4}$
(b) Weather deck fwd of $0{,}8L_R$ (*see* Note 3)		$Z = f_L\, s\, k_s\, (360h_1 + 0{,}0045\, (l_e L_1)^2) \times 10^{-4}$
(c) Weather deck aft of $0{,}075L_R$		$Z = 0{,}0067 s\, k_s\, h_1\, l_e^2$ or (a) above whichever is greater
(3) Lower decks (a) Stores, machinery and hangar decks	(i) effective	$Z = s\, k_s\, (5{,}4L_1 + 23h_2\, l_e^2) \times 10^{-4}$
	(ii) non effective	$Z = 0{,}0045 s\, k_s\, h_2\, l_e^2$
(b) Accommodation decks (*see* Note 1)	(i) effective	$Z = s\, k_s\, (4{,}7L_1 + 23h_2\, l_e^2) \times 10^{-4}$
	(ii) non effective	$Z = 0{,}0039 s\, k_s\, h_2\, l_e^2$
(4) Strength deck in way of superstructure		To be specially considered

Symbols

ρ, L_1, L_2, s, k_s as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1*

D, T, L_R as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*

F_D as defined in *Vol 1, Pt 6, Ch 3, 3.6 Local reduction factors*

$$C_1 = \frac{60}{225 - 165F_D}$$

d_w = web depth of longitudinal, in mm, *see* Note 2

F_1 = $0{,}25C_1$

l_e = as defined in *Vol 1, Pt 6, Ch 2, 2.6 Determination of span length*, but not to be taken less than 1,5 m

h_{T1} = the greater of $\frac{L_1}{70}$ or 1,20 m

$$f_{FB} = \frac{0{,}0914 + 0{,}003L_R}{D - T} - 0{,}15$$

h_2 = deck pressure head (*see* Note 4)

= 2,6 for machinery spaces, workshops or hangers

= 2,0 for stores

= 1,2 for accommodation decks and void spaces

= h_m for general cargo spaces

h_m = general cargo deck pressure head, to be taken as equivalent to the pressure head produced by filling the hold to its full depth at a stowage rate of 1,39 m^3/tonne, unless specified otherwise (*see* Note 6).	
fwd of 0,925L_R	
f_L = 1,57	
h_1 = 1,8	
from 0,88L_R to 0,925L_R	
f_L = 1,43	
h_1 = 1,5	
aft of 0,88L_R	
f_L = 1,23 (*see* Note 3)	
h_1 = 1,2 + 2,04 f_{FB}	
Note 1. Where weather decks are intended to carry deck equipment and the load is in excess of 8,5 kN/m^2, the scantlings of longitudinals will be specially considered.	
Note 2. The web depth of longitudinals, d_w is to be not less than 60 mm.	
Note 3. For taper end modulus calculation f_L = 1,23 at 0,925L_R	
Note 4. Where the deck forms the boundary of a tank, the additional requirements of *Table 3.3.5 Watertight and deep tank bulkhead and deck scantlings* for deep tanks are to be applied.	
Note 5. The modulus of strength deck longitudinals from 0,075L_R to 0,3L_R and 0,7L_R to 0,925L_R is to be determined by assuming a linear taper from the midship value (1) to the basic weather deck value (2) at 0,075L_R and 0,925L_R. The modulus determined is not to be less than 2(b) or 2(c), as appropriate, *see Vol 1, Pt 6, Ch 3, 3.7 Taper requirements for hull envelope*. The total area of longitudinals at 0,075L_R is not to be less than 50 per cent of the midship's value.	
Note 6. If the hold does not have a uniform cross-section the breadth and/or length averaged over the averaged depth, to an equivalent rectangular section, may be used when determining the volume of the hold.	

Table 3.3.8 Deck beams (transverse framing)

Location	Modulus, in cm^3
(1) Strength, weather and exposed decks	The lesser of the following:(a) $Z = \left(K_1 K_2 T D + K_3 B_1 s h_1 l_e^2\right) k_s \times 10^{-4}$ (b) $Z = 2 K_3 B_1 s k_s h_1 l_e^2 \times 10^{-4}$
(2) Lower decks	
(a) Stores, machinery and hangar decks	$Z = (360 K_1 T D + 35 s h_2 l_e^2) k_s \times 10^{-4}$
(b) Accommodation decks	$Z = (480 K_1 T D + 35 s h_2 l_e^2) k \times 10^{-4}$
Symbols	
s, k_s as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1*	
B, D, T as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*	

d_w = depth of beam, in mm

h_1 = strength/weather deck head in metres, *see Table 3.3.7 Deck longitudinals (longitudinal framing)*

h_2 = deck pressure head in metres, *see Table 3.3.7 Deck longitudinals (longitudinal framing)*

l_e as defined in *Vol 1, Pt 6, Ch 2, 2.6 Determination of span length* but to be taken as not less than 1,83 m

B_1 = B, but need not be taken greater than 21,5 m

K_1 = a factor dependent on the number of decks (including poop and bridge superstructures) at the position of the beam under consideration:

1 deck	18,0	3 decks	9,5
2 decks	12,0	4 or more	8,4

K_2 = a factor dependent on the location of the beam:

at short bridge and poops	133
fwd of 0,88L_R	800
elsewhere	530

K_3 = a factor dependent on the location of the beam:

span adjacent to the ship side	3,3
fwd of 0,925L_R	5,0
elsewhere	3,0

Note 1. Where weather decks are intended to carry deck cargo and the load is in excess of 8,5 kN/m^2, the scantlings of beams may be required to be increased to comply with the requirements for location (2).

Note 2. The web depth of beams, d_w, is to be not less than 60 mm.

Note 3. Where decks form the boundary of a tank, the additional requirements of *Table 3.3.5 Watertight and deep tank bulkhead and deck scantlings* for deep tanks is to be applied.

3.12.3 Deck primary structure for both longitudinally and transversely framed ships is to comply with the following requirements:

(a) Girders and transverses or deep beams in way of dry spaces:

(i) supporting up to three point loads Z to be determined using calculations based on a stress of 123,5/ks N/mm^2, assuming fixed ends and the inertia given as follows:

$$I = \frac{1,85}{k_s} l_e Z \text{ cm}^4$$

(ii) supporting four or more point loads or a uniformly distributed load

$$Z = 4,75 k_s S H_g l^2{}_e \text{cm}^4$$

$$I = \frac{1,85}{k_s} l_e Z \text{ cm}^4$$

(b) Girders and transverses in way of the crown or bottom of a tank

$$Z = 11,7 k_s h_4 S l^2{}_e \text{cm}^3$$

$I = \frac{2,8}{k_s} l_e Z \ cm^4$

whereH_g = weather head h_1, or deck pressure head h_2, in metres as given in *Table 3.3.7 Deck longitudinals (longitudinal framing)* h_4 = tank head, in metresl_e = effective span length in metres as defined in *Vol 1, Pt 6, Ch 2, 2.6 Determination of span length*

S, k_s are as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1*.

3.12.4 The thickness of the deck plating is in no case to be less than the appropriate minimum requirements given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*

3.12.5 Additional requirements for deck structures are indicated in *Vol 1, Pt 6, Ch 3, 10 Deck structures*

3.13 Superstructures, deckhouses and bulwarks

3.13.1 The thickness of deck plating is to be as required by *Table 3.3.9 Superstructure plating*.

Table 3.3.9 Superstructure plating

Location	Thickness, in mm
(1) Superstructure and deckhouse fronts, sides and backs	$t = 0,00126s\ \beta\ \sqrt{k_s P_{dh}}$
(2) Exposed decks in superstructures and deckhouses	$t = 0,00126s\ \beta\ \sqrt{k_s P_{wd}} + 1,5$
(3)Internal decks in superstructures and deckhouses	$t = 0,0017s\ \beta\ \sqrt{k_s P_{in}}$
Symbols	
s, f, k_s are as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1* P_{dh} = deckhouse pressure, *see Vol 1, Pt 5, Ch 3, 5.5 Loads for deckhouses, bulwarks and superstructures, Pdh* P_{wd} = weather deck pressure, *see Vol 1, Pt 5, Ch 3, 3.5 Pressure on exposed and weather decks, Pwd* P_{in} = internal deck pressure, *see Vol 1, Pt 5, Ch 3, 5.3 Pressure on internal decks, Pin* β = aspect ratio correction factor, *see Vol 1, Pt 6, Ch 2, 2.5 Aspect ratio correction 2.5.1*	
Note Deckhouses and superstructures subjected to hull girder stress are to comply with the buckling requirements of *Vol 1, Pt 6, Ch 2, 3 Buckling*.	

3.13.2 The scantlings of deckhouse and superstructure side, ends and deck stiffening are to comply with the requirements of *Table 3.3.10 Superstructure framing*

Table 3.3.10 Superstructure framing

Location	Modulus, in cm^3
Superstructure and deckhouse fronts, sides and backs:side longitudinals and side frames (*see* Note 1)	$Z = 0,0006 P_{dh} s k_s l_e^2$
Exposed decks:deck beams and deck longitudinals, (*see* Note 2)	The greater of the following: (a) $= Z = 0,0006 P_{wd} s k_s l_e^2$ (b) $= Z = 0,025s$

Internal decks:deck beams and deck longitudinals	The greater of the following: (a) $= Z = 0,0006 P_{\text{in}} s k_{\text{s}} l^{2}_{\text{e}}$ (b) $= Z = 0,025 s$
Symbols	
s, k_{s} as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1* l_{e} = effective length of stiffening member as defined in *Vol 1, Pt 6, Ch 2, 2.6 Determination of span length* f_{FB} = *see Table 3.3.7 Deck longitudinals (longitudinal framing)* P_{dh} = deckhouse pressure, *see Vol 1, Pt 5, Ch 3, 3.5 Pressure on exposed and weather decks, Pwd* P_{wd} = weatherdeck pressure, *see Vol 1, Pt 5, Ch 3, 3.5 Pressure on exposed and weather decks, Pwd* P_{in} = internal deck pressure, *see Vol 1, Pt 5, Ch 3, 5.3 Pressure on internal decks, Pin*	
Note 1. The section modulus of side frames forming part of the side shell is to comply with the requirements for shell envelope framing. Note 2. The section modulus of superstructure stiffening is not to be less than that required by *Table 3.3.7 Deck longitudinals (longitudinal framing)* and *Table 3.3.8 Deck beams (transverse framing)* for full width superstructures.	

3.13.3 The section modulus of deck girders and transverses is to be in accordance with the requirements of *Vol 1, Pt 6, Ch 3, 3.12 Deck structures 3.12.3* using H_{g} equal to 0,1P_{wd}, 0,1P_{dh} or 0,1P_{in} as appropriate, where P_{wd}, P_{dh} and P_{in} are defined in *Vol 1, Pt 5, Ch 3, 3.5 Pressure on exposed and weather decks, Pwd*

3.13.4 The thickness of the superstructures and deckhouses is in no case to be less than the appropriate minimum requirements given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*

3.13.5 Additional requirements for superstructures, deckhouses and bulwarks are indicated in *Vol 1, Pt 6, Ch 3, 11 Superstructures, deckhouses and bulwarks*

3.13.6 Superstructure deckhouse and bulwark stiffeners are to be continuous or efficiently bracketed top and bottom. Where this is impractical the modulus is to be increased by 20 per cent and the ends welded to the deck all round.

3.14 Single and double bottom structures

3.14.1 Single bottom scantlings are to comply with the appropriate minimum requirements given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements* For the forward region, the requirements of *Table 3.3.12 Single bottom construction forward, minimum requirements* are to be complied with.

3.14.2 Double bottom scantlings are to comply with *Table 3.3.11 Double bottom requirements (0,2L $_{R}$ to 0,8L $_{R}$)* and the appropriate minimum requirements given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*

Table 3.3.11 Double bottom requirements (0,2L_{R} to 0,8L_{R})

Location	Thickness, in mm
Inner bottom plating,(*see* Note)	$t = 0,00122(s+660)(k_s^2 L_R T)^{0,25}$
Longitudinal framing	modulus, in cm^3

Inner bottom longitudinals	The greater of the following: (a) $Z = \left(0,0017 l_{e1} + 0,035\right) s k_s h_{T2} l_e^2 F_s F_1$ (b) $Z = \left(0,0017 l_{e1} + 0,035\right) s k_s h_{T3} l_e^2 F_s F_1$
Transverse framing	
Inner bottom transverse frames	$Z = 1,7 s k_s T l_e x 10^{-2}$
Symbols	
s, k_s are as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1* L_R, T are as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars* l_{e1}, l_e, h_{T2}, h_{T3}, F_1 are as defined in *Table 3.3.2 Shell envelope framing (0,2L R to 0,8L R)* F_s is as defined in *Table 3.3.3 Shell envelope framing forward and aft*	
Note The thickness of the margin plate, where fitted, is to be increased by 20 per cent.	

Table 3.3.12 Single bottom construction forward, minimum requirements

Area	Item	Requirement
Longitudinal framing minimum requirements		
Centreline girder:	Thickness, in mm	$t = \left(0,007\,d_f + 1\right)\sqrt{k_s}$ $t = \left(0,006\,d_f + 1\right)\sqrt{k_s}$ but need not exceed $12\sqrt{k_s}$
Floors and Girders	Thickness, in mm Depth (d_f), in mm	As midship region, *see Table 3.2.1 Minimum structural requirements*
Bottom Transverses	Spacing, in m	*See Vol 1, Pt 3, Ch 2, 3.4 Shell framing 3.4.4*
Transverse framing minimum requirements		
Centreline girder	Thickness, in mm	$t = 0,95\sqrt{L_R k_s}$ but not less than 6 mm forward of $0,925L_R$. Between $0,925L_R$ and $0,7L_R$ the thickness may taper to the midship thickness
	Modulus, in cm^3	the greater of: $Z = 8 k_s S h_5 l_e^2$ $Z = 8 k_s S h_4 l_e^2$
	Inertia, in cm^4	$I = \frac{2,5 l_e^2 Z}{k_s}$
Floors in tanks	Spacing	every frame
	Depth, in mm	$d_f = 83D + 150$ or 1400 whichever is less
	Thickness, in mm	$t = \left(5,5 + 0,023 L_2\right)\sqrt{S_2/800}$
	Face plate area, in cm^2	$A_f = 0,8 S k_s B$
Girders in tanks	Spacing, in metres	$0,003 s_f$
	Depth, in mm	as for floors
	Scantlings	as midship region, *see Table 3.2.1 Minimum structural requirements*
Floors in dry spaces	Spacing	every frame

	Scantlings	as midship region, *see Table 3.2.1 Minimum structural requirements*
Girders in dry spaces	Spacing, in mm	0,003s_f
	Scantlings	as midship region, *see Table 3.2.1 Minimum structural requirements*
Symbols		

L_2, S, s, k_s, ρ are as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1*

L_R, B, D are as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*

l_e = effective length of stiffening member

h_4 = tank head, in metres, as defined in *Table 3.3.5 Watertight and deep tank bulkhead and deck scantlings*

h_5 = distance, in metres, from mid-point of span to the following positions:

(a) forward of 0,85L_R: 3 m above the deck height obtained from *Vol 1, Pt 3, Ch 2, 5.3 Minimum bow height and extent of forecastle*

(b) at 0,8L_R: the upper deck at side

(c) between 0,85L_R and 0,8L_R, by interpolation between (a) and (b)

s_F = transverse frame spacing, in mm

s_2 = spacing of stiffener, in mm, but to be taken not less than 800 mm

Note 1. For ships having one or more longitudinal bulkheads the maximum spacing may be increased but is not to exceed that for the midship region.

Note 2. Frame structure is to comply with the requirements of *Table 3.3.5 Watertight and deep tank bulkhead and deck scantlings*

Note 3. *See also* the requirements for bottom slamming and bow flare impact.

3.14.3 In the forward region, the requirements of *Table 3.3.13 Double bottom construction forward* are to be complied with.

Table 3.3.13 Double bottom construction forward

Item and parameter	Requirements	
	Transverse framing	Longitudinal framing
(1) Centreline girder: (a) Thickness forward of 0,075L_R from the F.P.	$t = (0{,}007\ d_{DB} + 2)\sqrt{k_s}$ mm (*see* Note 2)	
(2) Plate floors: (a) Maximum spacing forward of 0,8L_R	0,002s_F m	2,5 m
(b) Maximum spacing aft of 0,8L_R	As for midship region	As for midship region, *see Table 3.2.1 Minimum structural requirements*
(c) Scantlings	As for midship region	As for midship region, *see Table 3.2.1 Minimum structural requirements*
(3) Watertight floors and bracket floors	As for midship region	As for midship region

(4) Side girders (*see* Note 1):		
(a) Maximum spacing forward of $0,8L_R$	$0,003s_F$ m	$0,004s_L$ or 3,7 m whichever is the lesser
(b) Maximum spacing aft of $0,8L_R$	As for midship region	As for midship region, *see Table 3.2.1 Minimum structural requirements*
(c) Scantlings	As for midship region	As for midship region, *see Table 3.2.1 Minimum structural requirements*
(5) Inner bottom plating (*see* Note 2):		
(a) Thickness at or forward of $0,925L_R$	$t = \left(0,00115(s+660)\sqrt[4]{k^2{}_s L_R T}\right)$ mm or 5,5 mm, whichever is the greater, *see* Note 2	
(b) In way of deep tanks or holds used for the carriage of water ballast or where the double bottom tank is common with a wing ballast tank	$t = 0,0057S\beta\sqrt{h_4 k_s}$ mm or 5,5 mm, whichever is the greater	
(6) Inner bottom longitudinals	As for midship region	
Symbols		
L_R, T are as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*		
S, s, k_s are as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1*		
d_{DB} = minimum depth of centre girder as required by *Table 3.2.1 Minimum structural requirements*		
h_4 = tank head, in metres, as defined in *Table 3.3.6 Deck plating*		
s_F = transverse frame spacing, in mm		
s_L = spacing of bottom longitudinals, in mm		
β = aspect ratio correction factor, *Vol 1, Pt 6, Ch 2, 2.5 Aspect ratio correction 2.5.1*.		
Note 1. The girders forward of $0,8L_R$ are to be suitably scarfed into the midship girder arrangement.		
Note 2. From $0,7L_R$ to $0,925L_R$ the taper thickness is to be used.		

3.14.4 Additional requirements for single and double bottom structures are indicated in *Vol 1, Pt 6, Ch 3, 7 Single bottom structures* and *Vol 1, Pt 6, Ch 3, 8 Double bottom structures*.

3.14.5 Where there are large unsupported areas of double bottom and single bottom structure, the designer's calculations are to be submitted.

3.15 Fore peak structure

3.15.1 Internal structure in the fore peak is to comply with the requirements of *Table 3.3.14 Fore peak structure*

Table 3.3.14 Fore peak structure

Item	Parameter	Requirements
(1) Perforated flats and wash bulkheads excluding lowest strake of plating (*see* Note)	Plating thickness Stiffener modulus	$t = 5{,}5 + 0{,}013L_R \sqrt{s_1/800}$ mm $Z = \dfrac{0{,}0052 s k_s h_6 l_e^2}{f_s}$
(2) Diaphragms in bulbous bows and the lowest strake of plating	Plating thickness	$t = (5{,}5 + 0{,}23L_R) \sqrt{s_1/800}$ mm
Symbols		
L_R is as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars* s, k_s are as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1* f_s = 1,4 for rolled or built sections 1,6 for flat bars h_6 = vertical distance, in metres, from the mid depth of the tank to the top of the tank.	l_e = effective length of the stiffening member, *see Vol 1, Pt 6, Ch 2, 2.6 Determination of span length* s_1 = spacing of stiffeners, in mm, but to be taken not less than 800 mm	
Note For horizontal flats supporting vertical webs in the fore peak tank the thickness of the flat in the web is to comply with the requirements of $t = a/(80 + 20a/b)\sqrt{k_s}$ for horizontal stiffening or $t = a/(73 + 27(a/b)^2)\sqrt{k_s}$ for vertical stiffening Note where a is the lesser dimension of the unstiffened plate panel b is the greater dimension of the unstiffened plate panel.		

Table 3.3.15 Magazine bulkhead and deck scantlings

Item and requirement	Magazine bulkheads and decks
Plating	
(1) Plating thickness for plane, symmetrically corrugated and double plate bulkheads	$t = 0{,}004 s \beta \sqrt{h_5 k_5}$ mm
Secondary stiffening	
(2) Modulus of rolled and built stiffeners	$Z = \dfrac{s k_s h_5 l_e^2}{71 f_s(\omega_1 + \omega_2 + 2)}$ cm^3
Primary stiffening	
(3) Modulus of stringers or webs supporting vertical or horizontal stiffening	$Z = 5{,}0 k_s h_5 S l_e^2$ cm^3
Symbols	

s, S, k_s as defined in *Table 3.2.1 Minimum structural requirements* l_e = effective length of stiffening member in metres and for bulkhead stiffeners, *see Figure 3.3.3 Bulkhead end constraint factors* f_s = 1,4 for rolled or built sections and double plate bulkheads = 1,6 for flat bars = 1,0 for symmetrical corrugations of magazine bulkheads h_5 = $0,1P_{mag}$ P_{mag} is the quasi-static design pressure defined in *Vol 1, Pt 5, Ch 3, 5.11 Design pressure for magazine decks and bulkheads* $\omega 1$ and $\omega 2$ are bulkhead end constraint factors, *see Figure 3.3.3 Bulkhead end constraint factors* β = aspect ratio correction factor, *see Vol 1, Pt 6, Ch 2, 2.5 Aspect ratio correction 2.5.1*
Note Corrugated bulkheads are to comply with the requirements of *Vol 1, Pt 6, Ch 2, 2.3 Section properties*. Both the plate panels and section inertia and modulus requirements are to be assessed.

3.16 Magazine structure

3.16.1 Magazine structure which is assessed in accordance with *Vol 1, Pt 4, Ch 1, 6.4 Structure* is to comply with the requirements of *Table 3.3.15 Magazine bulkhead and deck scantlings*.

■ *Section 4*
NS2 and NS3 scantling determination

4.1 General

4.1.1 The scantlings for NS2 and NS3 ships may be determined from the global and local requirements defined in this Section. In addition, the general requirements of *Vol 1, Pt 6, Ch 3, 5 Shell envelope plating* to *Vol 1, Pt 6, Ch 3, 15 Strengthening for wave impact loads above waterline* are to be complied with.

4.1.2 This section contains various Tables indicating the design pressures, beam models and stiffener type coefficients which may be used in conjunction with the appropriate scantling formulae indicated in *Vol 1, Pt 6, Ch 2 Design Tools* and the structural design factors in *Vol 1, Pt 6, Ch 5 Structural Design Factors* to determine the required scantlings for both plating and stiffening members of NS2 and NS3 type ships.

4.1.3 In the determination of scantlings for stiffening members assumptions have been made about the degree of end fixity in way of their end connections. Where it can be demonstrated that the degree of end fixity is greater than that assumed then consideration will be given to lesser scantling requirements. In such cases the builders/designers are to submit sufficient information to enable an assessment of the degree of end fixity to be made and are to obtain acceptance of their proposals prior to submission of the scantling plans.

4.1.4 The geometric properties of stiffener sections are to be in accordance with *Vol 1, Pt 6, Ch 2, 2.9 Proportions of stiffener sections*

4.1.5 The scantlings in this Section are based on the assumption that the correct coatings are used and a proper maintenance regime is employed such that there is negligible loss in strength due to corrosion. For corrosion margins, *see Vol 1, Pt 6, Ch 6, 2.10 Corrosion margin*.

4.2 Hull girder strength

4.2.1 For all ships, the hull girder strength requirements of *Vol 1, Pt 6, Ch 4, 2 Hull girder strength* are to be complied with.

4.2.2 As required by *Vol 1, Pt 6, Ch 4, 2 Hull girder strength*, the hull girder bending and shear stresses for all longitudinally effective material is to be checked against the permissible stresses and the buckling requirements of *Vol 1, Pt 6, Ch 2, 3 Buckling*

The lateral and torsional stability of all effective longitudinals, together with the web and flange buckling criteria, is to be verified in accordance with *Vol 1, Pt 6, Ch 2, 3 Buckling*.

4.3 Shell envelope plating

4.3.1 The requirements of this Section are applicable to longitudinally and transversely framed shell envelope plating.

4.3.2 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirement given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*

4.3.3 Additional requirements for shell envelope plating are indicated in *Vol 1, Pt 6, Ch 3, 5 Shell envelope plating*

4.3.4 The thickness requirement for shell envelope plating may be determined from the general equations given in *Vol 1, Pt 6, Ch 2, 2.7 Plating general*, the pressures given in *Table 3.4.1 Shell envelope plating* and the structural design factors in *Vol 1, Pt 6, Ch 5 Structural Design Factors*.

Table 3.4.1 Shell envelope plating

Structural element	Design pressure
Bottom plating Bilge plating Side shell plate Sheerstrake	Below waterline, the greater of (a) $P_h + 1{,}26P_W$ (b) $1{,}26P_{dl}$ Above the waterline $1{,}26P_s$
Symbols	

P_h = the hydrostatic pressure on the shell plating, as defined in *Vol 1, Pt 5, Ch 3, 3.3 Hydrostatic pressure on the shell plating, Ph*

P_w = the hydrodynamic wave pressure on the shell plating, as defined in *Vol 1, Pt 5, Ch 3, 3.4 Hydrodynamic wave pressure, Pw*

P_s = the design pressure on the shell envelope, as defined in *Vol 1, Pt 5, Ch 3, 3.2 Combined hydrostatic and hydrodynamic pressure on the shell plating, Ps*

P_{dl} = the bottom impact pressure for planing hull forms as defined in *Vol 1, Pt 5, Ch 3, 4.5 Bottom impact pressure for ships operating in the planing regime* This is not applicable for displacement hull forms.

4.3.5 For NS3 ships the minimum thickness requirement for bottom shell plating, *see Figure 3.4.1 Extent of bottom shell*, as detailed in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*, is to extend to the chine line or 150 mm above the design waterline, whichever is the greater.

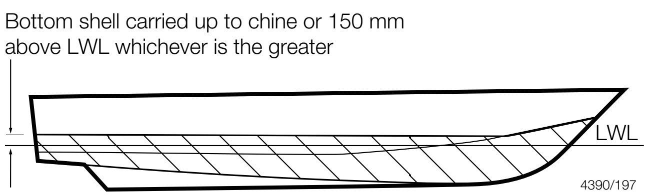


Figure 3.4.1 Extent of bottom shell

4.3.6 Where a chine or knuckle is fitted between the bottom shell and side shell plating, the chine plate thickness is to be equivalent to the bottom shell thickness required to satisfy the Rule pressure loading, increased by 20 per cent, or 6 mm, whichever is the greater.

4.3.7 Where tube is used in chine construction, the minimum wall thickness is to be not less than the thickness of the bottom shell plating increased by 20 per cent.

4.3.8 Full penetration welding of shell plating in way of chine is to be maintained.

4.3.9 Chine details are to be such that the continuity of structural strength across the panel is maintained. Details of chines are to be submitted for consideration, *see Figure 3.4.2 Chine detail*

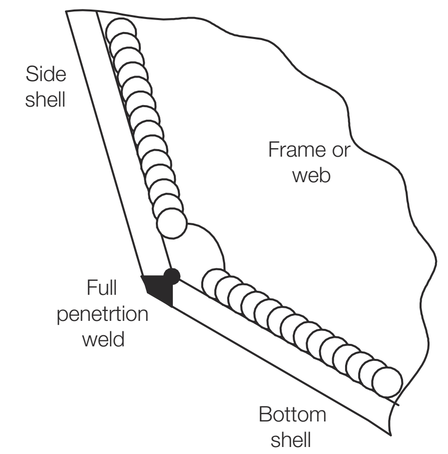


Figure 3.4.2 Chine detail

4.4 Shell envelope framing

4.4.1 The requirements of this Section are applicable to longitudinally and transversely framed shell envelopes.

4.4.2 Additional requirements for shell envelope framing are indicated in *Vol 1, Pt 6, Ch 3, 6 Shell envelope framing*

4.4.3 The section modulus, inertia and web area requirements for shell envelope stiffening may be determined from the general equations given in *Vol 1, Pt 6, Ch 2, 2.8 Stiffening general*, the pressures given in *Table 3.4.2 Shell envelope framing* and the structural design factors in *Vol 1, Pt 6, Ch 5 Structural Design Factors*

Table 3.4.2 Shell envelope framing

Structural element	Design pressure	Load model	Stiffening type factor, δ_f	Remarks
Longitudinal framing				
Bottom and bilge longitudinals Side longitudinals	Below waterline (a) δ_f (P_h + 1,26P_w) (b) δ_f 1,26 P_{dl} Above waterline δ_f 1,26P_s	B	0,8	*See* Note 1
Transverse framing				
Bottom transverse frames Side frames	Below waterline (a) δ_f (P_h + 1,26P_w) (b) δ_f (P_h + 1,26 P_{dl}) Above waterline δ_f 1,26P_s	B	0,8	*See* Note 1
Primary structure				
Bottom girders Side stringer Floors Bottom transverse web frames Side transverse web frames	Below waterline (a) δ_f (P_h + 1,26P_w) (b) δ_f 1,26 P_{dl} Above waterline δ_f 1,26P_s	A	0,5	*See* Note 2
Symbols				
P_h = the hydrostatic pressure on the shell envelope, as defined in *Vol 1, Pt 5, Ch 3, 3.3 Hydrostatic pressure on the shell plating, Ph* P_w = the hydrodynamic wave pressure on the shell envelope, as defined in *Vol 1, Pt 5, Ch 3, 3.4 Hydrodynamic wave pressure, Pw* P_s = the design pressure on the shell envelope, as defined in *Vol 1, Pt 5, Ch 3, 3.2 Combined hydrostatic and hydrodynamic pressure on the shell plating, Ps* P_{dl} = the bottom impact pressure for planing hull forms, as defined in *Vol 1, Pt 5, Ch 3, 4.5 Bottom impact pressure for ships operating in the planing regime* This is not applicable for displacement hull forms.				
Note 1. Longitudinal and transverse frame stiffeners are secondary stiffening members, *see Vol 1, Pt 3, Ch 2, 2.3 Definitions and structural terms 2.3.1* In general, secondary stiffening members, are to be designed using beam model 'B', *see Table 2.2.1 Section modulus, inertia and web area coefficients for different load models*. Such members are in general to be continuous or made effectively continuous by means of suitable bracketing. Note 2. Guidelines for the design of primary stiffening members are given in *Vol 1, Pt 3, Ch 2, 3.2 Primary members 3.2.1*. In general, primary stiffening members are to be designed using load model 'A', *see Table 2.2.1 Section modulus, inertia and web area coefficients for different load models*. Primary members are to be substantially bracketed at their end connections.				

4.5 Inner bottom structures

4.5.1 The requirements of this Section are applicable to longitudinally and transversely framed inner bottom structure.

4.5.2 The thickness of the inner bottom plating is in no case to be less than the appropriate minimum requirement given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*.

4.5.3 Additional requirements for inner bottom structures are indicated in *Vol 1, Pt 6, Ch 3, 8 Double bottom structures*.

4.5.4 The thickness requirement for inner bottom plating may be determined from the general equations given in *Vol 1, Pt 6, Ch 2, 2.7 Plating general*, the pressures given in *Table 3.4.3 Inner bottom structures* and the structural design factors in *Vol 1, Pt 6, Ch 5 Structural Design Factors*

Table 3.4.3 Inner bottom structures

Structural element	Design pressure	Beam model	Stiffening type factor, δ_f	Remarks
Inner bottom plating	$P_{hd} + 1{,}26P_{w,da}$	—	—	
Longitudinal framing				
Inner bottom longitudinals	$\delta_f (P_{hd} + 1{,}26P_{w,da})$	B	0,8	*See* Note 1
Transverse framing				
Inner bottom transverse frames	$\delta_f (P_{hd} + 1{,}26P_{w,da})$	B	0,8	*See* Note 1
Symbols				

P_{hd} = is the P_h value for the local damaged draft, where P_h is the hydrostatic pressure on the shell envelope, as defined in *Vol 1, Pt 5, Ch 3, 3.3 Hydrostatic pressure on the shell plating, Ph*

$P_{w,da}$ = the hydrodynamic wave pressure on the shell envelope, P_w, as defined in *Vol 1, Pt 5, Ch 3, 3.4 Hydrodynamic wave pressure, Pw*, but based on a reduction in the local wave height for the damaged situation. The local wave height factor, f_{Hs}, used to derive P_w may be taken as specified in *Vol 1, Pt 5, Ch 3, 1.2 Environmental conditions 1.2.2* but may be reduced by a factor of 1,85.

Hence $P_{w,da}$ = $P_w/1{,}85$

Note 1. Longitudinal and transverse frame stiffeners are secondary stiffening members, *see Vol 1, Pt 3, Ch 2, 2.3 Definitions and structural terms 2.3.1*. In general, secondary stiffening members are to be designed using load model 'B', *see Table 2.2.1 Section modulus, inertia and web area coefficients for different load models*. Such members are in general to be continuous or made effectively continuous by means of suitable bracketing.

Note 2. Where the inner bottom forms the boundary of a deep tank, the deck is to be examined for compliance with the requirements for deep tanks, *see Table 3.4.4 Watertight and deep tank bulkhead scantlings*

Note 3. Where the inner bottom forms the boundary of a watertight subdivision, the inner bottom is to be examined for compliance with the requirements for watertight bulkheads, *see Table 3.4.4 Watertight and deep tank bulkhead scantlings*

Note 4. Where the inner bottom is subject to cargo deck or internal deck loadings, the inner bottom is to be examined for compliance with the requirements for lower decks and internal decks, *see Table 3.4.5 Deck structures*

Note 5. Where the inner bottom is subject to wheel loadings arising from vehicles or helicopters/aircraft, the inner bottom is to be examined for compliance with the requirements for vehicle decks, *see Vol 1, Pt 4, Ch 3, 2 Vehicle decks and fixed ramps*, or aircraft operation, *see Vol 1, Pt 4, Ch 2, 10 Aircraft operations*, as appropriate.

4.5.5 The section modulus, inertia and web area requirements for inner bottom stiffening may be determined from the general equations given in *Vol 1, Pt 6, Ch 2, 2.8 Stiffening general*, the pressures given in *Table 3.4.3 Inner bottom structures* and the structural design factors in *Vol 1, Pt 6, Ch 5 Structural Design Factors*

4.6 Watertight bulkheads and deep tanks

4.6.1 The requirements of this Section are applicable to longitudinally and transversely framed watertight bulkhead and deep tank structure.

4.6.2 The thickness of the bulkhead plating is in no case to be less than the appropriate minimum requirement given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*

4.6.3 Additional requirements for watertight bulkhead and deep tank structure are indicated in *Vol 1, Pt 6, Ch 3, 9 Bulkheads and deep tanks*

4.6.4 The thickness requirement for bulkhead plating may be determined from the general equations given in *Vol 1, Pt 6, Ch 2, 2.7 Plating general*, the pressures given in *Table 3.4.4 Watertight and deep tank bulkhead scantlings* and the structural design factors in *Vol 1, Pt 6, Ch 5 Structural Design Factors*

4.6.5 The section modulus, inertia and web area requirements for bulkhead stiffening may be determined from the general equations given in *Vol 1, Pt 6, Ch 2, 2.8 Stiffening general*, the pressures given in *Table 3.4.4 Watertight and deep tank bulkhead scantlings* and the structural design factors in *Vol 1, Pt 6, Ch 5 Structural Design Factors*

Table 3.4.4 Watertight and deep tank bulkhead scantlings

Structural element	Design pressure	Beam model	Stiffening type factor, δ_f	Remarks
(1) Watertight bulkheads and decks				
Plating	P_{bhp}	–	–	
Secondary stiffeners	P_{bhs}	B	–	*See* Note 1
Primary stiffeners	P_{bhs}	A	–	*See* Note 2
(2) Deep tank bulkheads and decks				
Plating	P_{bhp}	–	–	
Secondary stiffeners	P_{bhs}	B	–	*See* Note 1
Primary stiffeners	P_{bhs}	A	–	*See* Note 2
(3) Collision bulkhead				
Plating	P_{bhp}	–	–	
Secondary stiffeners	P_{bhs}	B	–	*See* Note 1
Primary stiffeners	P_{bhs}	A	–	*See* Note 2
Symbols				
P_{bhp} and P_{bhs} = are the watertight bulkhead and deep tank pressure values of the plate panel and stiffener respectively, as defined in *Vol 1, Pt 5, Ch 3, 5.5 Loads for deckhouses, bulwarks and superstructures, Pdh*.				
P_{bhp} and P_{bhs} = pressure are the pressure values for the plate panel and stiffeners of the collision bulkhead as defined in *Vol 1, Pt 5, Ch 3, 5.9 Design pressures for collision bulkheads*				
Note 1. Secondary stiffening members are, in general, defined in *Vol 1, Pt 3, Ch 2, 2.3 Definitions and structural terms 2.3.1*. In general, secondary stiffening members are to be designed using load model 'B', *see Table 2.2.1 Section modulus, inertia and web area coefficients for different load models*. Such members are in general to be continuous or made effectively continuous by means of suitable bracketing.				
Note 2. Guidelines for the design of primary stiffening members are given in *Vol 1, Pt 3, Ch 2, 2.3 Definitions and structural terms 2.3.1* In general, primary stiffening members are to be designed using load model 'A', *see Table 2.2.1 Section modulus, inertia and web area coefficients for different load models*. Primary members are to be substantially bracketed at their end connections.				

4.7 Deck structures

4.7.1 The requirements of this Section are applicable to longitudinally and transversely framed deck structure.

4.7.2 The thickness of the deck plating is in no case to be less than the appropriate minimum requirement given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*

4.7.3 Additional requirements for deck structures are indicated in *Vol 1, Pt 6, Ch 3, 10 Deck structures*

4.7.4 The thickness requirement for deck plating may be determined from the general equations given in *Vol 1, Pt 6, Ch 2, 2.7 Plating general*, the pressures given in *Table 3.4.5 Deck structures* and the structural design factors in *Vol 1, Pt 6, Ch 5 Structural Design Factors*

4.7.5 The section modulus, inertia and web area requirements for deck stiffening may be determined from the general equations given in *Vol 1, Pt 6, Ch 2, 2.8 Stiffening general*, the pressures given in *Table 3.4.5 Deck structures*and the structural design factors in *Vol 1, Pt 6, Ch 5 Structural Design Factors*

Table 3.4.5 Deck structures

Structural element	Design pressure	Beam model	Stiffening type factor, δ_f	Remarks
(1) Weather decks and exposed decks				
Plating	The greater of (a) 1,26P_{wd} (b) P_{cd}	—	—	—
Secondary stiffening Deck longitudinals or deck beams	The greater of (a) δ_f 1,26P_{wd} (b) P_{cd}	B	0,8	*See* Note 1
Primary stiffening Deck girders or deck transverses or deep beams	The greater of (a) δ_f 1,26P_{wd} (b) P_{cd}	A	0,5	*See* Note 2
(2) Lower decks and internal decks				
Plating	The greater of (a) P_{in} (b) P_{cd}	—	—	—
Secondary stiffening Deck longitudinals or deck beams	The greater of (a) P_{in} (b) P_{cd}	B	—	*See* Note 1
Primary stiffening Deck girders or deck transverses or deep beams	The greater of (a) P_{in} (b) P_{cd}	A	—	*See* Note 2
(3) Ramps and lifts				
Plating	P_{ra}	—	—	—
Secondary stiffening Deck longitudinals or deck beams	P_{ra}	B	—	*See* Note 1
Primary stiffening Deck girders or deck transverses or deep beams	P_{ra}	E	—	*See* Note 3
Symbols				

P_{wd}	=	the pressure acting on exposed and weather decks, as defined in *Vol 1, Pt 5, Ch 3, 3.5 Pressure on exposed and weather decks, Pwd*, *see also Vol 1, Pt 5, Ch 3, 5.2 Pressure on external decks*
P_{in}	=	the pressure acting on internal decks, as defined in *Vol 1, Pt 5, Ch 3, 5.3 Pressure on internal decks, Pin*
P_{cd}	=	the pressure acting on decks designed to carry cargo or heavy equipment loads, as defined in *Vol 1, Pt 5, Ch 3, 5.4 Loads for decks designed for cargo or heavy equipment loads, Pcd and Wcd*, where appropriate
P_{ra}	=	the pressure on ramps and lifts, as defined in *Vol 1, Pt 5, Ch 3, 6.2 Loads for ramps and lifts, Pra*

Note 1. In general, secondary stiffening members are to be designed using load model 'B', *see Table 2.2.1 Section modulus, inertia and web area coefficients for different load models*. Such members are in general to be continuous or made effectively continuous by means of suitable bracketing.

Note 2. Guidelines for the design of primary stiffening members are given in *Table 3.2.1 Rudder profile coefficient, K_2* In general, primary stiffening members are to be designed using load model 'A', *see Table 2.2.1 Section modulus, inertia and web area coefficients for different load models*. Primary members are to be substantially bracketed at their end connections.

Note 3. In general, primary lift and ram stiffening members are to be designed using load model 'E', *see Table 2.2.1 Section modulus, inertia and web area coefficients for different load models*

Note 4. Where a deck forms the boundary of a deep tank, the deck is to be examined for compliance with the requirements for deep tanks, *see Table 3.4.4 Watertight and deep tank bulkhead scantlings*

Note 5. Where a deck forms the boundary of a watertight subdivision or part of the shell envelope, the deck is to be examined for compliance with the requirements for watertight bulkheads, *see Table 3.4.4 Watertight and deep tank bulkhead scantlings*, or the shell envelope respectively, *see Table 3.4.2 Shell envelope framing*

Note 6. Where a deck is subject to wheel loadings arising from vehicles or helicopters/aircraft, such decks are to be examined for compliance with the requirements for vehicle decks, *see Vol 1, Pt 4, Ch 3, 2 Vehicle decks and fixed ramps*, or aircraft operation, *see Vol 1, Pt 4, Ch 2, 10 Aircraft operations*, as appropriate.

4.8 Superstructures, deckhouses and bulwarks

4.8.1 The requirements of this Section are applicable to longitudinally and transversely framed superstructure, deckhouse and bulwark structures.

4.8.2 The thickness of the superstructure and deckhouse plating is in no case to be less than the appropriate minimum requirement given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*

4.8.3 Additional requirements for superstructure, deckhouse and bulwark structures are indicated in *Vol 1, Pt 6, Ch 3, 11 Superstructures, deckhouses and bulwarks*

4.8.4 The thickness requirement for superstructure, deckhouse and bulwark may be determined from the general equations given in *Vol 1, Pt 6, Ch 2, 2.7 Plating general*, the pressures given in *Table 3.4.6 Superstructure, deckhouse and bulwark structures* and the structural design factors in *Vol 1, Pt 6, Ch 5 Structural Design Factors*

4.8.5 The section modulus, inertia and web area requirements for superstructure, deckhouse and bulwark stiffening may be determined from the general equations given in *Vol 1, Pt 6, Ch 2, 2.8 Stiffening general*, the pressures given in *Table 3.4.6 Superstructure, deckhouse and bulwark structures* and the structural design factors in *Vol 1, Pt 6, Ch 5 Structural Design Factors*

Table 3.4.6 Superstructure, deckhouse and bulwark structures

Structural element	Design pressure	Beam model	Stiffening type factor, δ_f	Remarks
(1) Superstructure sides, fronts and backs Deckhouse sides, fronts and backs				
Plating	$1,26P_{dh}$	—	—	

Secondary stiffening Side longitudinals Side frames	δ_f 1,26P_{dh}	B	0,8	*See* Note 1
Primary stiffening Side stringers Side web frames	δ_f 1,26P_{dh}	A	0,5	*See* Note 2
(2) Superstructure exposed decks Deckhouse exposed decks				
Plating	1,26P_{wd}	—	—	
Secondary stiffening Deck longitudinals Deck beams	δ_f 1,26P_{wd}	B	0,8	*See* Note 1
Primary stiffening Deck girders Deck transverses or deep beams	δ_f 1,26P_{wd}	A	0,5	*See* Note 2
(3) Superstructure internal decks Deckhouse internal decks				
Plating	P_{in}	—	—	
Secondary stiffening Deck longitudinals Deck beams	P_{in}	B	—	*See* Note 1
Primary stiffening Deck girders Deck transverses or deep beams	P_{in}	A	—	*See* Note 2
(4) Bulwarks				

Plating	1,26P_{dh}	—	—	
Secondary stiffening Bulwark stays	δ_f1,26P_{dh}	B D	0,8 1,0	*See* Note 1 *See* Note 3
Symbols				
P_{wd} = the pressure acting on exposed and weather decks, as defined in *Vol 1, Pt 5, Ch 3, 3.5 Pressure on exposed and weather decks, Pwd*, *see also Vol 1, Pt 5, Ch 3, 5.2 Pressure on external decks* P_{in} = the pressure acting on internal decks, as defined in *Vol 1, Pt 5, Ch 3, 5.3 Pressure on internal decks, Pin* P_{dh} = the pressure acting on deckhouses, bulwarks and superstructures, as defined in *Vol 1, Pt 5, Ch 3, 5.5 Loads for deckhouses, bulwarks and superstructures, Pdh*				
Note 1. In general, secondary stiffening members are to be designed using load model 'B', *see Table 2.2.1 Section modulus, inertia and web area coefficients for different load models*. Such members are in general to be continuous or made effectively continuous by means of suitable bracketing. Note 2. Guidelines for the design of primary stiffening members are given in *Vol 1, Pt 3, Ch 2, 3.2 Primary members 3.2.1*. In general, primary stiffening members are to be designed using load model 'A', *see Table 2.2.1 Section modulus, inertia and web area coefficients for different load models*. Primary members are to be substantially bracketed at their end connections. Note 3. Bulwark stays are to be designed using load model 'D' *see Table 2.2.1 Section modulus, inertia and web area coefficients for different load models*. The webs of the stays are to be carefully aligned with underdeck stiffeners and hard spots are to be avoided in way of end connections. Note 4. Where a deck is subject to wheel loadings arising from vehicles or helicopters/aircraft, such decks are to be examined for compliance with the requirements for vehicle decks, *see Vol 1, Pt 4, Ch 3, 2 Vehicle decks and fixed ramps*, or aircraft operation, *see Vol 1, Pt 4, Ch 2, 10 Aircraft operations* as appropriate.				

■ *Section 5*
Shell envelope plating

5.1 General

5.1.1 The requirements of this Section, unless specified otherwise, are applicable to all ship types, NS1, NS2 and NS3.

5.1.2 The requirements of this Section are applicable to longitudinally and transversely framed shell envelope plating. The basic structural scantlings of NS1 ships are to be determined in accordance with *Vol 1, Pt 6, Ch 3, 3 NS1 scantling determination* The basic structural scantlings of NS2 and NS3 ships are to be determined in accordance with *Vol 1, Pt 6, Ch 3, 4 NS2 and NS3 scantling determination*. The arrangement of shell plating is to be in accordance with *Vol 1, Pt 3, Ch 2, 3.3 Shell plating*

5.1.3 The thickness of the shell envelope plating is in no case to be less than the appropriate minimum requirements given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*.

5.1.4 Ships which operate aground are to comply with the requirements of *Vol 1, Pt 4, Ch 3 Special Features*

5.1.5 For ships with external blast notation the side shell above the waterline is to be in accordance with *Vol 1, Pt 4, Ch 2 Military Load Specification*.

5.1.6 Where appropriate all ship types are to comply with the requirements of *Vol 1, Pt 6, Ch 3, 14 Strengthening for bottom slamming* for bottom slamming and *Vol 1, Pt 6, Ch 3, 15 Strengthening for wave impact loads above waterline* for bow flare impact or wave impact above the waterline.

5.2 Plate keel

5.2.1 The width and thickness of the plate keel are to be maintained throughout the ship from the transom to a point not less than 25 per cent of the freeboard (measured at the forward perpendicular) above the deepest load waterline on the stem. Thereafter the keel thickness may be reduced to that required by *Table 3.2.1 Minimum structural requirements* for the stem. For ships with an after cut up, the keel thickness aft of the cut up can be reduced to that of the shell plating.

5.2.2 Cast or forged stems are to comply with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials*, *Ch 3 Rolled Steel Plates, Strip, Sections and Bars* for rolled steel flat bars, or *Ch 5 Steel Forgings* for solid round bars. Cast or forged pieces or inserts are to comply with *Ch 4 Steel Castings* or *Ch 5 Steel Forgings* as appropriate.

5.3 Sheerstrake

5.3.1 The sheerstrake thickness is to be increased by 20 per cent at the ends of a superstructure extending out to the ship's side. In the case of a superstructure longer than 0,15L_R, the side plating at the ends of the superstructure is also to be increased by 25 per cent and tapered gradually into the sheerstrake.

5.3.2 Where an angled gunwale is fitted, the top edge of the sheerstrake is to be kept free of all notches and isolated welded fittings, such as spurnwaters, fairlead stools, stancheons. Bulwarks are not to be welded to the top of the sheerstrake within 0,3 to 0,7L_R.

5.3.3 Where a rounded gunwale is adopted, the welding of fairlead stools, spurnwaters, stancheons and other fittings to this plate is to be kept to the minimum, and the design of the fittings is to be such as to minimise stress concentration. The radius in general is not to be less than 15t_p.

5.3.4 For ships with a shock enhanced notation, *see Vol 1, Pt 4, Ch 2, 5 Underwater explosion (shock)*

5.4 Skegs

5.4.1 The thickness of the skeg plating is to be not less than the thickness of the adjacent bottom shell.

5.5 Transom

5.5.1 The thickness of the stern or transom is to be not less than that required for the side or bottom shell as appropriate. Where water jet or sterndrive units are fitted, the scantlings of the plating in way of the nozzles and connections will be specially considered.

5.6 Shell openings

5.6.1 The thickness of the shell envelope plating around sea inlet or other opening is to be 2 mm thicker than the adjacent shell plating, or 6 mm, whichever is the greater. Arrangements are to be in accordance with *Vol 1, Pt 3, Ch 2, 3.3 Shell plating*

5.6.2 The detail and steel grade corners of large openings in the side shell will be specially considered. Generally they are to be in accordance with the requirements for large deck openings, *see Vol 1, Pt 6, Ch 3, 10.4 Deck openings 10.4.1*

5.7 Sea inlet boxes

5.7.1 The thickness of the sea inlet box plating is to be 2 mm thicker than the adjacent shell plating, or 6 mm, whichever is the greater. If the thickness of the adjacent shell plating is greater than 12,5 mm, the sea inlet box may be the same thickness as the shell and it need not exceed 25 mm.

5.7.2 Arrangements are to be in accordance with *Vol 1, Pt 3, Ch 2, 3.3 Shell plating*. Stiffeners are to be suitably supported by brackets or equivalent.

5.8 Local reinforcement/Insert plates

5.8.1 The thickness of the shell envelope plating is to be increased locally in way of sternframe, propeller brackets, rudder horn, stabilisers, hawse pipes, anchor recess, sea inlets, sonar openings, etc. by generally not less than 50 per cent. Details of such reinforcement are to be submitted for approval.

5.8.2 Insert plates are to extend outside the line of adjacent supporting structure and then be tapered over a distance of not less than three times the difference in thickness, *see also Vol 1, Pt 6, Ch 6, 5.8 Insert plates*

5.9 Novel features

5.9.1 Where the Rules do not specifically define the requirements for novel features then the scantlings and arrangements are to be determined by direct calculation. Such calculations are be carried out on the basis of the Rules or recognised standards. Details are to be submitted for consideration.

■ *Section 6*
Shell envelope framing

6.1 General

6.1.1 The requirements of this Section, unless specified otherwise, are applicable to all ship types, NS1, NS2 and NS3.

6.1.2 The requirements in this Section apply to longitudinally and transversely framed shell envelopes. The basic structural scantlings of NS1 ships are to be determined in accordance with *Vol 1, Pt 6, Ch 3, 3 NS1 scantling determination*. The basic structural scantlings of NS2 and NS3 ships are to be determined in accordance with *Vol 1, Pt 6, Ch 3, 4 NS2 and NS3 scantling determination*. The arrangement of framing is to be in accordance with *Vol 1, Pt 3, Ch 2, 3.4 Shell framing*

6.1.3 The geometric properties of stiffener sections are to be in accordance with *Vol 1, Pt 6, Ch 2, 2.9 Proportions of stiffener sections*

6.1.4 Higher tensile steel longitudinals within 10 per cent of the ship's depth at the bottom and deck are to be continuous irrespective of the ship length, *see also Vol 1, Pt 6, Ch 6, 5.5 Arrangement at intersection of primary and secondary members*

6.1.5 Stiffeners and brackets on side transverses which are connected to higher tensile steel longitudinals are to have their heels well radiused to reduce stress concentrations. Alternative arrangements will be considered if supported by appropriate direct calculations, *see also Vol 1, Pt 6, Ch 6, 5.5 Arrangement at intersection of primary and secondary members*

6.1.6 Where higher tensile steel side longitudinals pass through transverse bulkheads in the 0,4L_R amidships, well radiused brackets of the same material are to be fitted on both the fore and aft side of the connection. Particular attention should be given to ensuring the alignment of these brackets. Alternative arrangements will be considered if supported by appropriate direct calculations.

6.1.7 Where higher tensile steel asymmetrical sections are adopted in double bottom tanks which are interconnected with double skin side tanks, the requirements of *Vol 1, Pt 6, Ch 3, 6.1 General 6.1.5* and *Vol 1, Pt 6, Ch 3, 6.1 General 6.1.6* are to be complied with regarding arrangements to reduce stress concentrations. Alternatively, it is recommended that bulb plate or symmetrical sections are adopted.

6.1.8 Where appropriate all ship types are to comply with the requirements of *Vol 1, Pt 6, Ch 3, 14 Strengthening for bottom slamming* for bottom slamming and *Vol 1, Pt 6, Ch 3, 15 Strengthening for wave impact loads above waterline* for wave impact above the waterline.

6.2 Frame struts or cross ties

6.2.1 Where struts are fitted to side shell transverse web frames or longitudinal stringers to carry axial loads, the strut cross-sectional area is to be derived as for pillars in *Vol 1, Pt 6, Ch 3, 12 Pillars and pillar bulkheads*. If the strut is fitted at the primary member half span point, the primary member section modulus may be taken as half the modulus derived above.

6.2.2 Design of end connections is to be such that the area of the welding is to be not less than the minimum required cross-sectional area of the strut. To achieve this, full penetration welding may be required. The weld connections between the face flats and webs of the supporting structure are to be welded using double continuous welding of an equivalent area.

Section 7
Single bottom structures

7.1 General

7.1.1 The requirements of this Section, unless specified otherwise, are applicable to all ship types, NS1, NS2 and NS3.

7.1.2 The basic structural scantlings of NS1 ships are to be determined in accordance with *Vol 1, Pt 6, Ch 3, 3 NS1 scantling determination*. The basic structural scantlings of NS2 and NS3 ships are to be determined in accordance with *Vol 1, Pt 6, Ch 3, 4 NS2 and NS3 scantling determination* The arrangement of single bottoms are to be in accordance with *Vol 1, Pt 3, Ch 2, 3.5 Single bottom structure*.

7.1.3 The scantlings of the single bottom are to comply with the minimum requirements given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*

7.1.4 Where appropriate all ships are to comply with the requirements of *Vol 1, Pt 6, Ch 3, 14 Strengthening for bottom slamming* for bottom slamming.

7.1.5 Watertight girders and floors or girders and floors forming the boundaries of tank spaces are to comply with the requirements for watertight bulkheads and deep tanks as detailed in *Vol 1, Pt 6, Ch 3, 9 Bulkheads and deep tanks*. For corrosion margins, *see Vol 1, Pt 6, Ch 6, 2.10 Corrosion margin*

7.2 Centreline girder

7.2.1 The web depth of the centreline girder is in general to be equal to the depth of the floors at the centreline. The minimum requirements for web depth and thickness are specified in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*

7.2.2 The geometric properties of the centre girder are to be in accordance with *Vol 1, Pt 6, Ch 2, 2.9 Proportions of stiffener sections*. The buckling requirements of *Vol 1, Pt 6, Ch 2, 3 Buckling* are to be satisfied.

7.2.3 The face flat area of the centreline girder outside 0,3 to 0,7L_R may be 80 per cent of the value given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*

7.2.4 The face flat thickness is to be not less than the thickness of the web.

7.2.5 The ratio of the width to thickness of the face flat is to be not less than 8 but is not to exceed 16.

7.3 Side girders

7.3.1 The face flat area and thickness of side girders are to comply with the requirements for plate floors as defined in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements* and *Vol 1, Pt 6, Ch 3, 7.4 Floors - general*. The buckling requirements of *Vol 1, Pt 6, Ch 2, 3 Buckling* are to be satisfied.

7.4 Floors - general

7.4.1 The web thickness, t_w, of plate floors, is to be accordance with *Vol 1, Pt 6, Ch 2, 2.9 Proportions of stiffener sections* and is to be taken as not less than:

for NS1 ships

$$t_{\mathrm{w}} = 0,9\sqrt{k_{\mathrm{s}}}\left(\frac{d_{\mathrm{f}}}{100} + 3\right)\mathrm{mm}$$

for NS2 and NS3 ships

$$t_{\mathrm{w}} = \sqrt{k_{\mathrm{s}}}\left(\frac{3,4d_{\mathrm{f}}}{1000} + 2,25\right)(S + 0,5)\ \mathrm{mm}$$

where

d_f is to be determined from *Table 3.2.1 Minimum structural requirements*

k_s and S are as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1*

Where the floor spacing, S is greater than 2,0 m it is recommended that the floor thickness is calculated by direct calculations.

7.4.2 In addition the area of face plate for NS1 ships is not to be less than

$$A_{\mathrm{f}} = 4,5T\,k_{\mathrm{s}}\ \mathrm{cm}^2$$

k_{s} is as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1*

T, *B* are as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*.

7.4.3 If the side frames of the ship are attached to the floors by brackets, the depth of floor may be reduced by 15 per cent and the floor thickness determined using the reduced depth. The brackets are to be flanged and have the same thickness as the floors, and their arm lengths clear of the frame are to be the same as the reduced floor depth given above.

7.4.4 The face flat thickness is to be not less than the thickness of the web plate. The ratio of the breadth of the face flat to the thickness of the face flat is to be not less than 8 but is not to exceed 16.

7.4.5 Additionally floors are to comply with the requirements for bottom transverse web frames.

7.5 Single bottom structure in machinery spaces

7.5.1 The arrangement of structure in machinery spaces is to be in accordance with *Vol 1, Pt 3, Ch 2, 6 Machinery space arrangements*

7.5.2 The thickness, t_{w}, of the floors in machinery spaces is to be 1 mm greater than that required by *Vol 1, Pt 6, Ch 3, 7.4 Floors - general*

7.5.3 The depth and section modulus of floors anywhere between engine or gearbox girders is to be not less than that required to maintain continuity of structural integrity or 50 per cent of the depth given in *Vol 1, Pt 6, Ch 3, 7.4 Floors - general* The face flat area and web thickness for such reduced floor heights are to be increased appropriately in order to maintain continuity of structural strength.

7.5.4 In way of machinery spaces situated amidships the minimum depth of floors is to be at least 10 per cent greater than that required in *Vol 1, Pt 6, Ch 3, 7.4 Floors - general*. If the top of the floors is recessed in way of the engines, the depth of the floors in way of the recess should generally be not less than that required by *Vol 1, Pt 6, Ch 3, 7.4 Floors - general*, but this will be specially considered in each case in relation to the arrangements proposed.

7.5.5 The general requirements for machinery or raft seatings are given in *Vol 1, Pt 6, Ch 3, 13 Machinery and raft seatings*.

7.6 Rudder horns

7.6.1 The shell plating thickness in way of the rudder horn is to be increased locally, by generally not less than 50 per cent but need not to be taken as greater than the keel thickness required by *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*. The scantlings of rudder horns will be specially considered.

7.7 Forefoot and stem

7.7.1 The thickness of plate stems at the waterline is to comply with the minimum requirements for plate keels given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*, *see also Vol 1, Pt 6, Ch 3, 5.2 Plate keel*

7.7.2 The forefoot and stem is to be additionally reinforced with floors.

■ *Section 8* Double bottom structures

8.1 General

8.1.1 The requirements of this Section, unless specified otherwise, are applicable to all ship types, NS1, NS2 and NS3.

8.1.2 The basic structural scantlings of NS1 ships are to be determined in accordance with *Vol 1, Pt 6, Ch 3, 3 NS1 scantling determination* The basic structural scantlings of NS2 and NS3 ships are to be determined in accordance with *Vol 1, Pt 6, Ch 3, 4 NS2 and NS3 scantling determination*. The scantlings of the double bottom structure are also to comply with the appropriate minimum requirements given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements* The arrangements of double bottoms are to comply with the requirements of *Vol 1, Pt 3, Ch 3, 2.6 Rudder profile coefficient, K2*

8.1.3 Where a double bottom is required to be fitted, its depth at the centreline, d_{DB}, is to be in accordance with *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*

8.1.4 This Section provides for longitudinal or transverse framing in the double bottom, but for NS1 and NS2 ships longitudinal framing is in general to be adopted. *See Vol 1, Pt 3, Ch 2, 3.1 General*

8.1.5 Where appropriate all ship types are to comply with the requirements of *Vol 1, Pt 6, Ch 3, 14 Strengthening for bottom slamming* for bottom slamming.

8.1.6 Where a floor, girder or inner bottom plating forms the boundary of a tank or part of the watertight subdivision, the requirements of *Vol 1, Pt 6, Ch 3, 9 Bulkheads and deep tanks* for deep tanks and watertight bulkheads are to be complied with. For corrosion margins, *see Vol 1, Pt 6, Ch 6, 2.10 Corrosion margin*

8.2 Centreline girder

8.2.1 A centreline girder is to be fitted throughout the length of the ship. The web thickness, t_{w}, is not to be less than that required by *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*

8.2.2 The geometric properties of the girder section are to be in accordance with *Vol 1, Pt 6, Ch 2, 2.9 Proportions of stiffener sections*. The buckling requirements of *Vol 1, Pt 6, Ch 2, 3 Buckling* are to be satisfied.

8.2.3 The depth of the double bottom and centreline girder is to be not less than 630 mm and it is to be sufficient to give access to all of the double bottom.

8.2.4 Where appropriate, vertical stiffeners are to be fitted at every bracket floor. They are to have a depth not less than the depth of the tank top frame or 150 mm, whichever is the greater. For NS2 and NS3 ships stiffeners are to have a depth of not less than $1{,}65L_{R}$ mm with a minimum of 50 mm. The thickness is to be as required for the girder.

8.3 Side girders

8.3.1 The thickness of the side girders is not to be less than that of the plate floors. The buckling requirements of *Vol 1, Pt 6, Ch 2, 3 Buckling* are to be satisfied.

8.3.2 Vertical stiffeners are to be fitted at every bracket floors fitted and if midway between floors in accordance with *Vol 1, Pt 6, Ch 3, 8.2 Centreline girder 8.2.4*

8.4 Plate floors

8.4.1 The thickness need not be greater than 15 mm but without suitable stiffening the ratio of depth of floor at the centre to thickness must be less than 130.

8.4.2 Vertical stiffeners are to be fitted to all plate floors at each longitudinal. Each stiffener is to have a depth of not less than $10t_{w}$ or 50 mm and a thickness of not less than t_{w}, where t_{w} is the thickness of the plate floor as calculated in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*. For NS1 ships, the depth of stiffeners is not to be less than 150 mm.

8.5 Bracket floors

8.5.1 Between plate floors, the shell and inner bottom plating centreline girders and side girders may be supported by bracket floors. The brackets are to have the same thickness as plate floors and are to be stiffened on the unsupported edge.

8.5.2 Where struts are fitted to reduce the unsupported span of the frames, reverse frames and longitudinals, they are to have a cross-sectional area of not less than:

(a) $A_{s} = 0{,}32 Z_{BF}$ cm^2 for $Z_{BF} \leq 83{,}5$ or

(b) $$A_{s} = 23{,}2 + \frac{Z_{BF}}{25} \text{ cm}^2 \text{ for } Z_{BF} > 83{,}5$$

where Z_{BF} is the modulus, in cm^3, of the frame or longitudinal based on the effective length between floors as defined in *Vol 1, Pt 6, Ch 2, 2.6 Determination of span length*

8.6 Additional requirements for watertight floors

8.6.1 The scantlings of watertight floors are to comply with the requirements for plate floors as given in *Vol 1, Pt 6, Ch 3, 8.5 Bracket floors*

8.7 Inner bottom plating

8.7.1 Where the inner bottom also acts as the plating of a vehicle deck, stores deck or similar, the requirements of *Vol 1, Pt 6, Ch 3, 10 Deck structures* are to be complied with.

8.8 Inner bottom longitudinals

8.8.1 Where the double bottom tanks are interconnected with side tanks or cofferdams, the scantlings are to be not less than those required for deep tanks, *see Vol 1, Pt 6, Ch 3, 9 Bulkheads and deep tanks*.

8.8.2 Higher tensile steel inner bottom longitudinals are to be continuous as far as practicable throughout the length of the ship.

8.9 Double bottom tanks

8.9.1 The scantlings of double bottom tanks are to comply with the requirements for deep tanks given in *Vol 1, Pt 6, Ch 3, 9 Bulkheads and deep tanks*

8.10 Margin plates

8.10.1 A margin plate, if fitted, is to have a thickness as required for inner bottom plating.

8.11 Double bottom structure in machinery rooms

8.11.1 The arrangements of the structure in machinery spaces are to be in accordance with *Vol 1, Pt 3, Ch 2, 6 Machinery space arrangements*

8.11.2 The scantlings of floors clear of the main engine seatings, are generally to be as required in *Vol 1, Pt 6, Ch 3, 8.4 Plate floors*. In way of engine seatings the floors are to be increased in thickness, *see Vol 1, Pt 6, Ch 3, 7.5 Single bottom structure in machinery spaces* and *Vol 1, Pt 6, Ch 3, 13 Machinery and raft seatings*

8.11.3 Where the double bottom is longitudinally framed and transverse floors are fitted in way of the engine seatings as required by *Vol 1, Pt 3, Ch 2, 6.6 Double and single bottom structure 6.6.4*, no additional longitudinal stiffening is required in way of the engines other than the main engine girders, provided that the spacing of girders does not exceed 1,5 times the normal spacing of longitudinals. Where this spacing of girders is exceeded, shell longitudinals are to be fitted. These are to scarf into the longitudinal framing clear of the machinery spaces. The scantlings of the longitudinals are to be determined in accordance with the appropriate requirements for bottom shell longituduals using a minimum span of 1,3 m.

■ *Section 9*
Bulkheads and deep tanks

9.1 General

9.1.1 The requirements of this Section, unless specified otherwise, are applicable to all ship types, NS1, NS2 and NS3.

9.1.2 The requirements of this Section apply to a vertical system of stiffening on bulkheads. They may also be applied to a horizontal system of stiffening provided that equivalent end support and alignment are provided.

9.1.3 The basic structural scantlings of NS1 ships are to be determined in accordance with *Vol 1, Pt 6, Ch 3, 3 NS1 scantling determination* The basic structural scantlings of NS2 and NS3 ships are to be determined in accordance with *Vol 1, Pt 6, Ch 3, 4 NS2 and NS3 scantling determination* The minimum requirements in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements* are also to be complied with. Arrangements are to be in accordance with *Vol 1, Pt 3, Ch 2, 3 Main hull structure* and *Vol 1, Pt 6, Ch 2, 3 Buckling*.

9.1.4 The buckling requirements of *Vol 1, Pt 6, Ch 2, 3 Buckling* are also to be satisfied.

9.1.5 The scantlings of bulkheads are to be suitably increased where bulkhead stiffeners support deck girders, transverses or pillars over, *see Vol 1, Pt 6, Ch 3, 12 Pillars and pillar bulkheads*.

9.1.6 For bulkheads in way of partially filled holds or tanks, sloshing forces may be required to be taken into account. Where such forces are likely to be significant, the scantlings will be required to be verified by additional calculations.

9.1.7 For RAS tanks or other tanks subjected to increased loads such loads are to be indicated on the plans submitted.

9.1.8 For ships with an internal blast notation certain bulkheads will require to be strengthened in accordance with *Vol 1, Pt 4, Ch 2 Military Load Specification*

9.2 Deep tank stiffening

9.2.1 Deep tank bulkhead stiffeners are to be bracketed at both ends. The thickness of the brackets is to be not less than the web thickness of the stiffener, *see Vol 1, Pt 6, Ch 6, 5 Construction details*

9.3 Gastight bulkheads

9.3.1 Where gastight bulkheads are fitted, in accordance with the requirements of *Vol 1, Pt 3, Ch 2, 4 Bulkhead arrangements* the general scantling equations for bulkheads, *see Vol 1, Pt 6, Ch 3, 3.12 Deck structures* for NS1 ships and *Vol 1, Pt 6, Ch 3, 4.6 Watertight bulkheads and deep tanks* for NS2 and NS3 ships, are to be complied with using a design pressure of 2 times the test pressure.

9.3.2 In addition the requirements for pillar bulkheads and minimum thickness requirements of *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements* are to be complied with where appropriate.

9.4 Non-watertight or partial bulkheads

9.4.1 Where a bulkhead is structural but non-watertight, the scantlings are in general to be as for watertight bulkheads or equivalent in strength to web frames/primary stiffeners in the same position.

9.4.2 Partial bulkheads which are neither watertight nor structural are to have scantlings and arrangements which are suitable for the intended purpose, such bulkheads are outwith the scope of classification.

9.5 Corrugated bulkheads

9.5.1 The plating thickness and section modulus for symmetrical corrugated bulkheads are to be in accordance with watertight bulkheads or deep tank bulkheads as appropriate. The spacing, s, is to be taken as b, as defined in *Figure 2.2.2 Corrugated section* in *Vol 1, Pt 6, Ch 2 Design Tools*

9.5.2 In addition, the section geometric properties of *Vol 1, Pt 6, Ch 2, 2.9 Proportions of stiffener sections* are to be complied with.

9.5.3 The actual section modulus may be derived in accordance with *Vol 1, Pt 6, Ch 2, 2.3 Section properties 2.3.1*

9.6 Wash plates

9.6.1 Stiffeners are to be fitted at every frame and efficiently bracketed at top and bottom.

9.6.2 The plate thickness is to be not less than the structural element from which the wash bulkhead is formed.

9.6.3 The general stiffener requirements are to be in accordance with *Vol 1, Pt 6, Ch 3, 3.11 Watertight bulkheads and deep tanks* for NS1 ships and 4.6 for NS2 and NS3 ships. However, the section modulus may be 50 per cent of that required if the end connections are bracketed.

9.6.4 The area of perforation is to be not less than 5 per cent and not more than 10 per cent of the total area of the bulkhead.

9.7 Cofferdams

9.7.1 The scantlings of cofferdams are to comply with the requirements of deep tank bulkheads or non-watertight bulkheads as appropriate.

■ *Section 10*
Deck structures

10.1 General

10.1.1 The requirements of this Section, unless specified otherwise, are applicable to all ship types, NS1, NS2 and NS3.

10.1.2 The basic structural scantlings of NS1 ships are to be determined in accordance with *Vol 1, Pt 6, Ch 3, 3 NS1 scantling determination*. The basic structural scantlings of NS2 and NS3 ships are to be determined in accordance with *Vol 1, Pt 6, Ch 3, 4 NS2 and NS3 scantling determination* The thickness of the deck plating is in no case to be less than the appropriate minimum requirement given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*. Arrangements of structures are to be in accordance with *Vol 1, Pt 3, Ch 2, 3.7 Deck structure*

10.1.3 The geometric properties of stiffener sections are to be in accordance with *Vol 1, Pt 6, Ch 2, 2.9 Proportions of stiffener sections*. Web depth of secondary longitudinals is in general not to be less than 60 mm.

10.1.4 Primary and secondary stiffener end connection arrangements are, in general, to be in accordance with *Vol 1, Pt 6, Ch 6, 5 Construction details*

10.1.5 For vehicle decks and areas for aircraft operations, the deck scantlings are to comply with the requirements of *Vol 1, Pt 4, Ch 3, 2 Vehicle decks and fixed ramps* and *Vol 1, Pt 4, Ch 2, 10 Aircraft operations* respectively. Areas of deck subject to blast loads are to comply with the requirements of *Vol 1, Pt 4, Ch 2, 9 Military installation and operational loads*

10.1.6 Decks forming the boundary of a tank are to comply with the requirements for the appropriate deck and are to be additionally examined for compliance with the requirements for deep tank plating.

10.1.7 Decks forming subdivision or watertight internal boundaries are to comply with the requirements for the appropriate deck and are to be additionally examined for compliance with the requirements for watertight plating and stiffening.

10.2 Deck plating

10.2.1 The thickness of the strength deck stringer plate is to be increased by 20 per cent at the ends of superstructures extending out to the ship side, deckhouses, poop and forecastle. The thickness of the strength deck is to be increased by 20 per cent in way of the corners of effective superstructures that are not full width.

10.3 Deck stiffening

10.3.1 Higher tensile steel deck longitudinals where used are to be continuous irrespective of the ship length.

10.3.2 The geometric properties of stiffener sections are to be in accordance with *Vol 1, Pt 6, Ch 2, 2.9 Proportions of stiffener sections*

10.3.3 The stiffening arrangements and end connection of primary supporting members are to be in accordance with *Vol 1, Pt 6, Ch 6, 5 Construction details*

10.3.4 Where the depth of web of a longitudinal girder at the strength deck within $0,3L_R$ to $0,7L_R$ exceeds:

(a) $55t_w$ for mild steel members
(b) $55t_w\sqrt{k_L}$ for higher tensile steel members

k_L is defined in *Vol 1, Pt 6, Ch 5, 3 Scantling determination for NS2 and NS3 ships*.

Additional longitudinal web stiffeners are to be fitted at a spacing not exceeding the value in (a) or (b) as appropriate, with a maximum of $65t_w\sqrt{k_L}$ for higher tensile steel members. In cases where this spacing is exceeded, the web thickness is, in general, to be suitably increased. Alternative proposals will be considered.

10.3.5 Web stiffeners may be flat bars of thickness t_w and depth $0,1d_w$, or 50 mm, whichever is greater. Alternative sections of equivalent inertia may be adopted.

10.4 Deck openings

10.4.1 The steel grade for the corner plating or inserts in way of large openings as required by *Vol 1, Pt 3, Ch 2, 3.7 Deck structure* for both NS1 and NS2 ships is to be in accordance with *Table 6.2.1 Material classes and grades* in *Vol 1, Pt 6, Ch 6 Material and Welding Requirements*. The required thickness of the insert plate is to be not less than 25 per cent greater than the adjacent deck thickness outside the line of openings with a minimum increase of 4 mm. The increase need not exceed 7 mm.

10.4.2 The steel grade for corner inserts in way of openings for lifts, or cut outs in the deck plating for side doors, etc. is to be Grade E or EH.

10.4.3 Welded attachments close to or on the free edge of the large opening corner plating are to be avoided. The butt welds of corner insert plates to the adjacent deck plating are to be located well clear of butts in the opening coaming or bulkheads.

10.4.4 Where minor deck openings, within 0,3L_R to 0,7L_R, have a total breadth or shadow area breadth in one transverse section that exceeds the limitation given in *Vol 1, Pt 6, Ch 4, 1.4 Calculation of hull section modulus 1.4.11* and *Vol 1, Pt 6, Ch 4, 1.4 Calculation of hull section modulus 1.4.12*, compensation will be required to restore the excess. This is generally to be arranged by increasing the deck plate thickness, but other proposals will be considered.

10.4.5 Plate panels in which openings are cut are to be adequately stiffened, where necessary, against compression and shear buckling. The corners of all openings are to be well rounded and the edges smooth.

10.4.6 Minor openings in the strength deck outside the line of major deck openings having a stress concentration factor in excess of 2,4 will require edge reinforcement in the form of a spigot of adequate dimensions, but alternative arrangements will be considered. The area of any edge reinforcement which may be required is not to be taken into account in determining the required sectional area of compensation for the opening. For example, elliptical openings having their major axis fore and aft and a ratio of length to breadth not less than 2 to 1 will not normally require edge reinforcement.

10.4.7 Where long, wide openings are arranged on lower decks, it may be necessary to increase the deck plating thickness to ensure effective support for side framing.

10.4.8 Lower deck openings should be kept clear of the corners of major openings and other areas of high stress, so far as possible. Compensation will not, in general, be required unless the total width of openings in any frame space, or between any two transverses, exceeds 15k_s per cent of the original effective plating width. The requirements of *Vol 1, Pt 6, Ch 3, 10.4 Deck openings 10.4.1* also apply to lower deck openings except that:

(a) the thickness of inserts, if required, for the lower deck large opening corners is to be 2,5 mm greater than the deck thickness;
(b) inserts will not generally be required for large opening corners on non-effective decks or platform decks; and
(c) reinforcement will not generally be required for circular openings, provided that the plate panels in which they are situated are otherwise adequately stiffened against compression and shear buckling.

10.5 Sheathing

10.5.1 The requirements for deck sheathing given in *Vol 1, Pt 6, Ch 3, 2.4 Sheathing* are to be complied with.

10.6 Decks used as ramps

10.6.1 Where any deck forms a ramp, such decks are to be examined for compliance with the requirements for cargo ramps, *see Vol 1, Pt 4, Ch 3, 5 Movable decks, lifts, internal and external ramps*

■ *Section 11*
Superstructures, deckhouses and bulwarks

11.1 General

11.1.1 The requirements of this Section, unless specified otherwise, are applicable to all ship types, NS1, NS2 and NS3.

11.1.2 The basic structural scantlings of NS1 ships are to be determined in accordance with *Vol 1, Pt 6, Ch 3, 3 NS1 scantling determination* The basic structural scantlings of NS2 and NS3 ships are to be determined in accordance with *Vol 1, Pt 6, Ch 3, 4 NS2 and NS3 scantling determination*. Arrangements of the structure are to be in accordance with the requirements of *Vol 1, Pt 3, Ch 2, 7 Superstructures, deckhouses, bulwarks, sponsons and appendages*

11.1.3 The plating thickness of superstructures, deckhouses and bulwarks is in no case to be less than the appropriate minimum requirements given in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*

11.1.4 Stiffener sections and geometric properties are to be in accordance with *Vol 1, Pt 6, Ch 2, 2.9 Proportions of stiffener sections*

11.1.5 For ships with an external blast notation, the superstructure strength is to be in accordance with *Vol 1, Pt 4, Ch 2, 2 External blast*

11.2 Forecastle requirements

11.2.1 The forecastle side plating may be a continuation of the hull side shell plating or fitted as a separate assembly. Where fitted as a separate assembly, suitable arrangements are to be made to ensure continuity of the effect of the sheerstrake at the break and at the upper edge of the forecastle side. Full penetration welding is to be used.

11.2.2 The deck plating thickness is to be increased by 20 per cent in way of the end of the forecastle if this occurs at a position aft of $0{,}75L_R$. No increase is required if the forecastle end bulkhead lies forward of $0{,}8L_R$. The increase at intermediate positions of end bulkhead is to be obtained by interpolation.

11.3 Superstructures formed by extending side structures

11.3.1 The side plating of such superstructures having a length of $0{,}15L_R$ or greater is to be increased in thickness by 25 per cent at the ends of the structure, and is to be tapered into the sheerstrake, *see Vol 1, Pt 6, Ch 3, 5.3 Sheerstrake 5.3.1* This plating is to be efficiently stiffened at the upper edge and supported by web plates not more than 1,5 m from the end bulkhead. Proposals for alternative arrangements, including the use of higher tensile steel, will be individually considered.

11.3.2 Where the superstructure contributes to the hull girder strength, the shear capability of the superstructure may need to be verified.

11.4 Mullions

11.4.1 The scantlings of mullions are to be not less than as required for a stiffener in the same position.

11.4.2 When determining the stiffener requirements, the width of effective plating is in no case to be taken as greater than the distance between adjacent window openings.

11.4.3 Where significant shear forces are to be carried by superstructures and deckhouses which have large windows, doors, vents and other openings in their side structures, adequate shear rigidity is to be verified by direct calculation.

11.5 Sheathing

11.5.1 Sheathing arrangements are to comply with the requirements of *Vol 1, Pt 6, Ch 3, 2.4 Sheathing*

■ *Section 12*
Pillars and pillar bulkheads

12.1 Application

12.1.1 The requirements of this Section, unless specified otherwise, are applicable to all ship types, NS1, NS2 and NS3. Arrangements of pillars are to be in accordance with*Vol 1, Pt 3, Ch 2, 8 Pillars and pillar bulkheads*

12.2 Determination of span length

12.2.1 The effective span length of the pillar, l_{ep}, is in general the distance between the head and heel of the pillar. Where substantial brackets are fitted, l_{ep} may be reduced by two thirds the depth of the bracket at each end.

12.3 Design loads

12.3.1 The design loading, L_{pi}, to be used in the determination of pillar scantlings is as follows:

$$L_{pi} = S_{gt}\, b_{gt}\, P_c + L_a \text{ kN}$$

where

L_{pi} = design load supported by the pillar, to be taken as not less than 5 kN

P_c = basic deck girder design pressure, as appropriate, plus any other loadings directly above the pillar, in kN/m^2

L_a = load from pillar or pillars above, assumed zero if there are no pillars over, in kN

where

S_{gt} = spacing, or mean spacing, of girders or transverses, in metres

b_{gt} = distance between centres of two adjacent spans of girders or transverses supported by the pillar, in metres.

12.4 Scantling determination

12.4.1 The minimum wall thickness of tubular pillars is to be in accordance with *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements*

12.4.2 The cross-sectional area of the pillar, A_p, is not to be less than:

$$A_{\mathrm{p}} = 10\frac{L_{\mathrm{pi}}}{\sigma_{\mathrm{p}}}\ \mathrm{cm}^2$$

where

L_{pi} = design load, in kN, supported by the pillar as determined from *Vol 1, Pt 6, Ch 3, 12.3 Design loads*

σ_p = permissible compressive stress, in N/mm^2

$$= \frac{f_{\mathrm{pi}}\sigma_o}{1 + 0,0051\ \sigma_{\mathrm{o}} C_{\mathrm{f}}\left(\frac{l_{\mathrm{ep}}}{r}\right)^2}\ \mathrm{N/mm}^2$$

where

f_{pi} = pillar location factor defined in *Table 3.12.1 Pillar location factors*

σ_o = specified minimum yield strength of the material, in N/mm^2

C_f = pillar end fixity factor

= 0,25 for full fixed/bracketed

= 0,50 for partially fixed

= 1,0 for free ended

r = least radius of gyration of pillar cross-section, in cm

$$= \sqrt{\frac{I_{\mathrm{p}}}{A_{\mathrm{p}}}}\ \mathrm{cm}$$

I_p = least moment of inertia of cross-section of pillar or stiffener/plate combination, in cm^4

l_{ep} = effective span of pillar, in metres, or bulkhead as defined in *Vol 1, Pt 6, Ch 3, 12.2 Determination of span length*

Table 3.12.1 Pillar location factors

Location	f_{pi}
Supporting weather deck	0,50
Supporting vehicle deck	0,50
Supporting stores equipment and routes	0,50
Supporting accommodation/inner deck	0,75
Supporting deckhouse top	1,00

12.5 Slenderness ratio

12.5.1 The slenderness ratio (l_e/r) of pillars should not in general exceed 1,1. Pillars with slenderness ratio in excess of 1,1 may be accepted subject to special consideration on a case by case basis and provided that the remaining requirements of the Rules are complied with.

12.6 Pillars in tanks

12.6.1 The tensile stress in the pillar and its end connections is not to exceed 108 N/mm^2 at the tank test pressure.

12.7 Pillar bulkheads

12.7.1 The stiffener/plate combination used in the determination of pillar bulkhead scantlings is to be that of a stiffener with an effective width of attached plating as determined from *Vol 1, Pt 6, Ch 2, 2.2 Effective width of attached plating, be*

12.7.2 The cross-sectional area of the pillar bulkhead, A_{pb}, is to be determined in accordance with *Vol 1, Pt 6, Ch 3, 12.4 Scantling determination* using the design loading, L_{pb}, as follows:

$$L_{pb} = S_{pb} B_{pb} P_c + L_c + L_p + L_a \text{ kN}$$

where

L_{pb} = design load supported by the stiffener plate combination of the pillar bulkhead, to be taken as not less than 5 kN

P_c = basic deck girder design pressure, as appropriate, directly above the pillar bulkhead, in kN/m^2

L_c = point loads applied to load area supported by the pillar bulkhead, and not included in P_c, in kN Point loads supported by the pillar bulkhead which should include point loads within the load patch plus point loads from outside the load patch, which distribute to the pillar bulkhead. Point loads which fall between pillar bulkheads should be shared proportionately between support points

L_p = load resulting from uniformly distributed loads on decks above, excluding the deck directly above, which have been carried through by pillars or pillar bulkheads above, in kN

L_a = point load, in kN, from above

= zero if there are no pillars or pillar bulkheads over

= 65 per cent of the point load from pillar bulkhead over, provided the pillar bulkhead spans between primary support points

= full load from pillar or pillars over

= full load from pillar bulkhead or pillar bulkheads over that do not span between primary support points

S_{pb} = spacing, or mean spacing, of bulkheads or effective transverses/longitudinal stiffeners, in metres

B_{pb} = distance between centres of two adjacent spans of girders or transverses supported by the pillar bulkhead, in metres, and can be taken as the distance between pillar bulkhead stiffeners where the stiffeners at the top of the bulkhead effectively distribute the load evenly into the stiffeners.

12.7.3 The thickness of the bulkhead plating is in no case to be taken as less than 4 mm

12.7.4 The scantlings of the pillar bulkhead are not to be less than those of any bulkhead or pillar bulkhead in the direct support line above that being considered.

12.8 Direct calculations

12.8.1 As an alternative to *Vol 1, Pt 6, Ch 3, 12.4 Scantling determination* and *Vol 1, Pt 6, Ch 3, 12.7 Pillar bulkheads*, pillars and pillar bulkheads may be designed on the basis of direct calculation. The method adopted and the stress levels proposed for the material of construction are to be submitted together with the calculations for consideration.

12.9 Novel features

12.9.1 Where unusual or novel pillars designs are proposed that are unable to comply with the requirements of this Section, their design together with the direct calculations are to be submitted for special consideration.

■ *Section 13*
Machinery and raft seatings

13.1 General

13.1.1 Main and auxiliary engine seatings are to be effectively secured to the hull structure. The scantlings of such seatings are to be adequate for the intended purpose, with due account taken of the gravitational, thrust, torque and vibrating forces together with the load increases resulting from sea motions and shock which may be imposed upon them.

13.1.2 In determining the scantlings of seats for oil engines, consideration is to be given to the general rigidity of the engine itself and to its design characteristics with regard to out of balance forces.

13.1.3 The longitudinal girders forming the engine seatings are to extend as far forward and aft as practicable and are to be adequately supported by transverse floors or brackets. The webs of the longitudinal girders are to be welded to the bottom shell plating.

13.1.4 The seats are to be so designed that they distribute the forces from the engine(s) as uniformly as possible into the supporting structure. Longitudinal girders supporting the seatings are to be arranged in single or double bottoms, and are, in general to extend over the full length of the machinery space. The ends of the girders are to be scarfed into the bottom structure for at least two frame spaces. Adequate transverse brackets are to be arranged in line with floors. Half floors, transverse brackets or hanging brackets will in general be required under the top plate in way of holding down bolts.

13.1.5 Where rafts are proposed for supporting the main and auxiliary engines the arrangements of such rafts are to be in accordance with *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*

13.1.6 Welding in way of all machinery seating is be double continuous and where appropriate full penetration.

13.1.7 Large areas of unstiffened flat plate are to be avoided.

13.1.8 The number openings of lightening holes in the seating structure are to be kept to the minimum necessary for access essential for maintenance, etc. Lightening holes are to be as small as practicable and are in no case to be greater than one half of the corresponding dimension of the plate in which they are positioned. Lightening holes with dimensions which are in excess of one third the corresponding dimension of the plate in which they are positioned are to be suitably edge stiffened by spigots or other equivalent means.

13.1.9 Machinery seatings are additionally to be examined for compliance with the bottom stiffening requirements as appropriate for their location, with due account taken of both local and global loadings.

13.2 Seats for oil engines

13.2.1 In determining the scantlings of seats for oil engines, consideration is to be given to the general rigidity of the engine itself and to its design characteristics in regard to out of balance forces.

13.2.2 In the case of higher power oil engines or turbine installations the seatings should generally be integral with the bottom structure. The tank top plating in way of the engine foundation plate or the turbine gear case and the thrust bearing should be substantially increased in thickness, *see Figure 3.13.1 Machinery and raft seatings*, Type 1.

13.2.3 If the main machinery is supported on seatings of Type 2 as shown in *Figure 3.13.1 Machinery and raft seatings*, these are to be so designed that they distribute the forces from the engine as uniformly as possible into the supporting structure. Longitudinal members supporting the seating are to be arranged in line with girders in the double bottom, and adequate transverse stiffening is to be arranged in line with floors, *see Figure 3.13.1 Machinery and raft seatings*, Type 2.

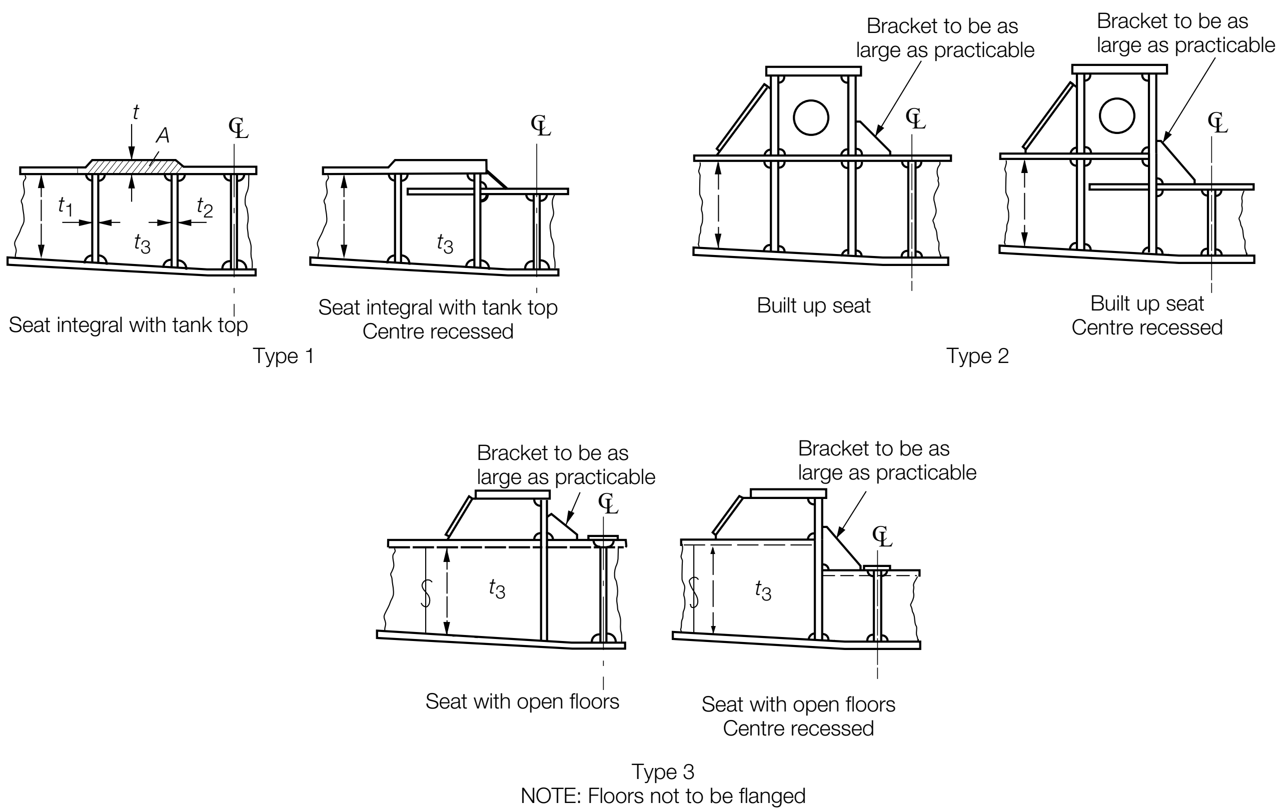


Figure 3.13.1 Machinery and raft seatings

13.2.4 In ships having open floors in the machinery space the seatings are generally to be arranged above the level of the top of floors and securely bracketed to them, *see Figure 3.13.1 Machinery and raft seatings*, Type 3.

13.3 Seats for turbines

13.3.1 Seats are to be so designed as to provide effective support for the turbines and ensure their proper alignment with the gearing, and (where applicable) allow for thermal expansion of the casings. In general, the seats are not to be arranged in way of breaks or recesses in the double bottom.

13.4 Seats for boilers

13.4.1 Boiler seats are to be of substantial construction and efficiently supported by transverse and horizontal brackets. These should generally be arranged in line with plate floors and girders in a double bottom or with suitable deep beams or transverses and girders at boiler flats. Suitable allowance is to be made in the design of the supporting structure for the variation in loading due to thermal expansion effects.

13.5 Seats for auxiliary machinery

13.5.1 Auxiliary machinery is to be secured on seatings, of adequate scantlings, so arranged as to distribute the loadings evenly into the supporting structure.

Section 14
Strengthening for bottom slamming

14.1 General

14.1.1 This section may be used to determine the additional scantlings for strengthening in respect of the bottom structure forward for NS1 and NS2 type ships.

14.1.2 The additional scantlings for strengthening in respect of the bottom structure forward for NS3 type ships will be specially considered on the basis of this Section.

14.2 Strengthening of bottom forward

14.2.1 The bottom forward is to be additionally strengthened where the ship has a draught forward of less than 0,045L_R in any operational loading condition. This minimum draught, T_{FB}, *see Vol 1, Pt 6, Ch 3, 14.2 Strengthening of bottom forward 14.2.7*, is to be indicated on the shell expansion plan, the plan showing the internal strengthening, the Loading Manual and loading instrument, where fitted.

14.2.2 The requirements for the additional strengthening apply to ships where L_R is greater than 65 m.

14.2.3 The scantling requirements outside the areas which have been strengthened for bottom slamming are to be suitably tapered to maintain adequate continuity of strength in both longitudinal and transverse directions.

Table 3.14.1 Additional strengthening of bottom forward

Item	Requirements	
(1) Longitudinally framed bottom shell plating (including keel) (*see* Notes 1 and 2)	$t = 0{,}003 s f \sqrt{h_s k_s}$	
(2) Bottom longitudinals – other than flat bars	$\frac{d_w}{t_w} \leq 55\sqrt{k_s}$ $\frac{d_w t_w}{100} \geq 0{,}00033 k_s h_s s\ c \left(S - \frac{s}{2000}\right) \text{cm}^2$ $Z \geq 6{,}8 \times 10^{-6} h_s s k_s \left[(17{,}5_{ls})^2 - (0{,}01s)^2 + d_w c\left(S - \frac{s}{2000}\right)\right] \text{cm}^3$ $\frac{\left(A_1 \overline{\tau} + \alpha\right)}{p} \times 10^{-1} \geq 1$ $A_w \geq 0{,}84 A_1$	
(3) Bottom longitudinals – flat bars	Will be specially considered	
	Transverse framing	Longitudinal framing

(4) Primary structure in way of single bottoms	(a) Centreline girder: Scantlings as required by *Table 3.3.12 Single bottom construction forward, minimum requirements* as appropriate, except that in determining Z in way of a deep tank forward of 0,8L_R the value of h_5 is to be increased by the following percentages: where $T_{FB} \le 0{,}03L_2$, 30 per cent where $T_{FB} \ge 0{,}04L_2$, 0 per cent The increase in h_5 for intermediate values of T_{FB} to be obtained by interpolation	(a) Ships having one or more longitudinal bulkheads: (i) Centreline girder Scantlings as required by *Table 3.3.12 Single bottom construction forward, minimum requirements* as appropriate (ii) Bottom transverses Maximum spacing as for midships region, scantlings as required by Section 2, as appropriate (iii) For horizontally stiffened longitudinal bulkheads and girders the depth to thickness ratio of the panel attached to the bottom shell plate is not to exceed 55 $\sqrt{k_s}$ (iv) Where T_{FB} <0,025L_2 the scantlings and arrangements will receive individual consideration
	(b) Floors: Scantlings as required by Table 3.3.12 as appropriate, except that in way of dry spaces the minimum face area is to be increased by the following percentages: where $T_{FB} \le 0{,}03L_2$, 50 per cent where $T_{FB} \ge 0{,}04L_2$, 0 per cent The increase of minimum face area for intermediate values of T_{FB} to be obtained by interpolation	(b) Other ship arrangements will receive individual consideration
	(c) Side girders: Arrangement and scantlings as required by *Table 3.3.12 Single bottom construction forward, minimum requirements* as appropriate, with the addition of intermediate half-height girders or equivalent fore and aft stiffening	

(5) Primary structure in way of double bottoms (*see* Note 3)	(a) Plate floors: Maximum spacing, every frame Scantlings as required by *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements* (b) Centreline and side girders: Maximum spacing, 0,003s_F m Scantlings as required by *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements* (c) Intermediate half-height girders to be arranged midway between side girders: Scantlings as required for non-watertight side girders by Section 2	(a) Plate floors: Maximum spacing: 0,002s_F m for T_{FB} < 0,04L_2 0,003s_F m for $T_{FB} \geq$ 0,04L_2 but not to exceed that required by *Table 3.3.12 Single bottom construction forward, minimum requirements* as appropriate (b) Centreline and side girders: Maximum spacing: 0,003s_L m for T_{FB} < 0,04L_2 0,004s_L m for $T_{FB} \geq$ 0,04L_2 but not to exceed that required by *Table 3.3.12 Single bottom construction forward, minimum requirements*, as appropriate Scantlings as required by *Table 3.3.12 Single bottom construction forward, minimum requirements*, as appropriate
(6) Primary structure in way of double bottoms supported by longitudinal bulkheads	—	The scantlings and arrangements will receive individual consideration on the basis of direct calculations using, if necessary, a suitably defined two-dimensional grillage model

Symbols

L_R, T as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*

L_2, S, $_s$, k_s as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1*

c = 1,0 for $S \leq 2,5$ m

= $(0,87 + 0,16S)\, c_1$ for $S > 2,5$ m

c_1 = 1,0 for $S \leq 1,0$ m

= $(1,14 - 0,14S)$ for 1,0 m < S ≤ 4,0 m

= $\frac{2,32}{S}$ for $S > 4,0$ m

d_w = web depth, in mm, see *Figure 2.2.1 Dimensions of longitudinals*

f = $\left(1,1 - \frac{s}{2500S}\right)$ but not greater than 1,0

h_s = equivalent slamming pressure, in metres, obtained from *Vol 1, Pt 6, Ch 3, 14.2 Strengthening of bottom forward 14.2.7* or *Vol 1, Pt 6, Ch 3, 14.2 Strengthening of bottom forward 14.2.8*

l_s = l_e, in metres, as defined in *Vol 1, Pt 6, Ch 2, 2.6 Determination of span length* where in way of a double bottom

= S, in metres, where in way of a single bottom

p = $9{,}81 h_s s c_1 \left[S - \frac{s}{2500}\right] \times 10^{-3}$ kN

s_F = spacing of transverse frames, in mm, for longitudinally framed side and bottom construction s_F may be taken as s_L

s_L = spacing of bottom longitudinals, in mm

t_w = web thickness, in mm

A_f = cross-sectional area of primary member web stiffener, in cm^2

A_{fc} = effective area of primary member web stiffener in way of butted end connection to the longitudinal, in cm^2

A_L = area of weld of lapped connection, in cm^2, calculated as total length of weld, in cm x throat thickness, in cm

A_w = area of weld of lug and web connection to the longitudinal, in cm^2, calculated as total length of weld in cm x throat thickness, in cm

A_1 = effective total cross-sectional area of the lug and web connection to the longitudinal, in cm^2

T_{FB} = draught, in metres, at the F.P., as defined in *Vol 1, Pt 6, Ch 3, 14.2 Strengthening of bottom forward 14.2.1*

α = $A_f \overline{\sigma}$ for the web stiffeners

= $A_{fc} \overline{\sigma}$ for a butted connection to the longitudinals

= $A_L \overline{\tau}$ for a lapped connection

$\overline{\sigma}$ = permissible direct stress, in N/mm^2, given in *Table 3.14.2 Permissible stresses*

$\overline{\tau}$ = permissible shear stress, in N/mm^2, given in *Table 3.14.2 Permissible stresses*

Note 1. If intermediate stiffening is fitted the thickness of the bottom shell plating may be 80 per cent of that required by (1) but is to be not less than the normal taper thickness.

Note 2. For transverse framing the bottom shell plating is to be specially considered.

Note 3. Particular care is to be taken to limit the size and number of openings in way of the ends of floors or girders or to fit suitable reinforcement where such openings are essential.

Note 4. The welding requirements of *Vol 1, Pt 6, Ch 6, 3 Requirements for welded construction* are also to be complied with.

Table 3.14.2 Permissible stresses

Item		Direct stress, σ [$d1$] in N/mm^2 *see* Note	Shear stress, τ [$d1$] in N/mm^2
Primary member web stiffener on area A_f	a) Flat bars (*see* Note)	$\frac{10,3}{k_s}\left[33-\frac{d}{t\sqrt{k_s}}\right]$	–
	(b) Bulb plates (*see* Note)	$\frac{8,6}{k_s}\left[40-\frac{d}{\left(\frac{100A_f}{d}-\frac{t}{6}\right)\sqrt{k_s}}\right]$	–
	(c) Inverted angles	$\frac{220}{k_s}$	–
Primary member web stiffener on area A_{fc}		$\frac{245}{k_s}$	–
Primary member web stiffener lapped to secondary member on area A_L		–	$\frac{167}{k_s}$
Lug or web connection on area $A1$	Single	–	$\frac{124}{k_s}$
	Double	–	$\frac{141}{k_s}$
Symbols			

A_f, A_L, A_1 are as defined in *Table 3.14.1 Additional strengthening of bottom forward* d = stiffener depth, in mm k_s as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1* t = stiffener web thickness, in mm
Note $\overline{\sigma}$ is to be taken no greater than $\frac{220}{k_s}$.

14.2.4 The scantling requirements for the additional strengthening are given in *Vol 1, Pt 6, Ch 3, 3.14 Single and double bottom structures 3.14.1*, or may be obtained by direct calculation. Where T_{FB} is less than 0,01L_R, the additional strengthening is to be specially considered.

14.2.5 Bottom longitudinals are to pass through and be supported by the webs of primary members. The vertical web stiffeners are to be connected to the bottom longitudinals. The cross-sectional area of the connections is to comply with the requirements given in *Table 3.14.1 Additional strengthening of bottom forward*

14.2.6 The scantlings required by this Section must in no case be less than those required by other Sections in *Vol 1, Pt 6, Ch 3, 3 NS1 scantling determination*

14.2.7 For NS1 ships with a block coefficient, C_b, greater than 0,6, the equivalent slamming pressure expressed as a head of water, h_s, is to be obtained from *Figure 3.14.1 Pressure heads* where, h_{max} is calculated from the following expressions:

$$65 < L_R \le 169\text{ m},\ h_{max} = 10\sqrt{L_R}\,F\text{ m}$$

$$L_R > 169\text{ m},\ h_{max} = 130F\text{ m}$$

where

$$F = 5,95 - 10,5\left(\frac{T_{FB}}{L_R}\right)^{0,2}$$

T_{FB} = is the minimum draft at the location under consideration

L_R is as defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*

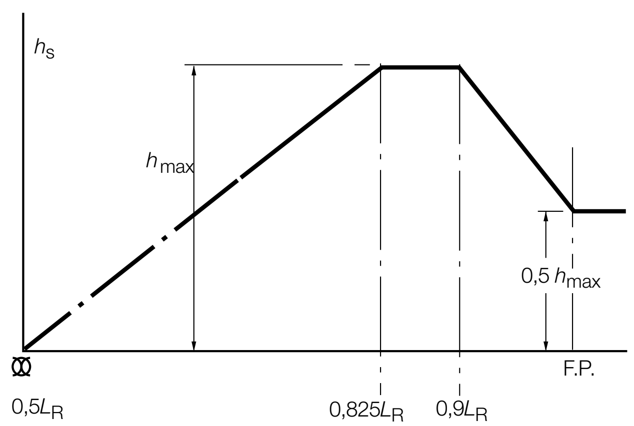


Figure 3.14.1 Pressure heads

14.2.8 For NS1 ships where C_b < 0,6 and for NS2 and NS3 ships, the equivalent bottom impact pressure head, h_s, is to be derived in accordance with the following:

$$h_s = \frac{IP_{bi}}{10}\text{ m}$$

where

IP_{bi} = instantaneous bottom impact pressure as given in *Vol 1, Pt 5, Ch 3, 4.2 Bottom impact pressure, IPbi*

Section 15
Strengthening for wave impact loads above waterline

15.1 General

15.1.1 This Section may be used to determine the required scantlings for strengthening against bow flare slamming for NS1 and NS2 type ships and for wave impacts on the shell envelope. Direct calculations may also be used to determine the required scantling.

15.1.2 The required scantlings for strengthening against wave impact loads for NS3 type ships will be specially considered on the basis of this Section.

15.1.3 The scantling requirements contained in this Section are based on no permanent set of plating. If acceptable, special consideration will be given to an alternative plating performance standard where specified. Areas designed in accordance with an alternative performance specification are to be clearly marked on the plans. Direct calculations may be used to determine the required scantlings.

15.2 Strengthening against bow flare wave impacts

15.2.1 The shell envelope above the design waterline is to be strengthened against bow flare wave impact pressures. The strengthening is to extend vertically to the uppermost deck level, including the forecastle deck, if fitted.

15.2.2 The equivalent bow flare wave impact head, h_s, is to be taken as:

$$h_s = \frac{IP_{bf}}{10}\text{ m}$$

where

IP_{bf} is the bow flare or above waterline wave impact pressure, *see Vol 1, Pt 5, Ch 3, 4.3 Bow flare and wave impact pressures, IPbf*

15.2.3 The thickness of the side shell is to be not less than:

$$t = 3,2 s_c \sqrt{k_s h_s} C_R \times 10^{-2}\text{mm}$$

where

s_c = spacing of secondary stiffeners, in mm, measured along a chord between parallel adjacent members or equivalent supports, as shown in *Figure 3.15.1 Chord spacing and mean chord spacing for secondary members*

h_s = bow flare wave impact head, in metres, as defined in *Vol 1, Pt 6, Ch 3, 15.2 Strengthening against bow flare wave impacts 15.2.2*

C_R = panel ratio factor

= $\left(\frac{l}{S_c}\right)^{0,41}$ but is not to be taken less than 0,06 or greater than 0,1

l = overall panel length, in metres, measured along a chord between the primary members

k_s = as defined in *Vol 1, Pt 6, Ch 3, 3.2 Symbols 3.2.1*

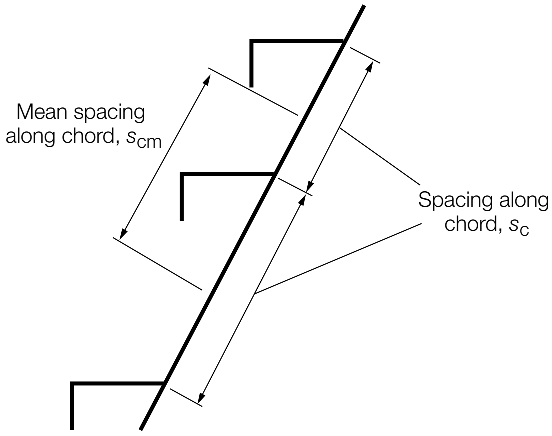


Figure 3.15.1 Chord spacing and mean chord spacing for secondary members

15.2.4 The scantlings of primary members are not to be less than:

(a) Section modulus of primary members

$$Z = 2\,\gamma\,z\,k_s\,h_s q\,v\,l^2_e\ \mathrm{cm}^3$$

(a) Web area of primary members

$$A = 0,2\ \gamma_A k_s\,h_s q\,v\,l_e\ \mathrm{cm}^2$$

(a) The web of the primary member is to be adequately stiffened.

where

h_s = bow flare wave impact head, in metres, as defined in *Vol 1, Pt 6, Ch 3, 15.2 Strengthening against bow flare wave impacts 15.2.2*

= and

= γ_A and γ_Z are strength factors dependant on the load position

for $q < 1$ $\gamma_A = q^3 - 2q^2 + 2$ and $\gamma_Z = 3q^3 - 8q^2 + 6q$

for $q = 1$ $\gamma_A = 1$ and $\gamma_Z = 1$

$$q = \frac{u}{l_e}\ \text{but}\ \leq 1$$

for web frames:

u = is the minimum of g_{bfv} or l_e

v = is the minimum of g_{bfh} or S_{cm}

for primary stringers:

where

u = is the minimum of g_{bfh} or l_e

v = is the minimum of g_{bfv} or S_{cm}

where

l_e = is the effective length of the primary member, in m

where

S_{cm} = is the mean spacing between primary members along the plating, in m, *see Figure 3.15.2 Mean spacing between primary members, S cm and the extents of the bow flare wave impact pressure, g bfh and g bfv*

g_{bfv} and g_{bfh} are defined in *Vol 1, Pt 5, Ch 3, 4.3 Bow flare and wave impact pressures, IPbf 4.3.3*

Other symbols are as defined in *Vol 1, Pt 6, Ch 2, 1 General*.

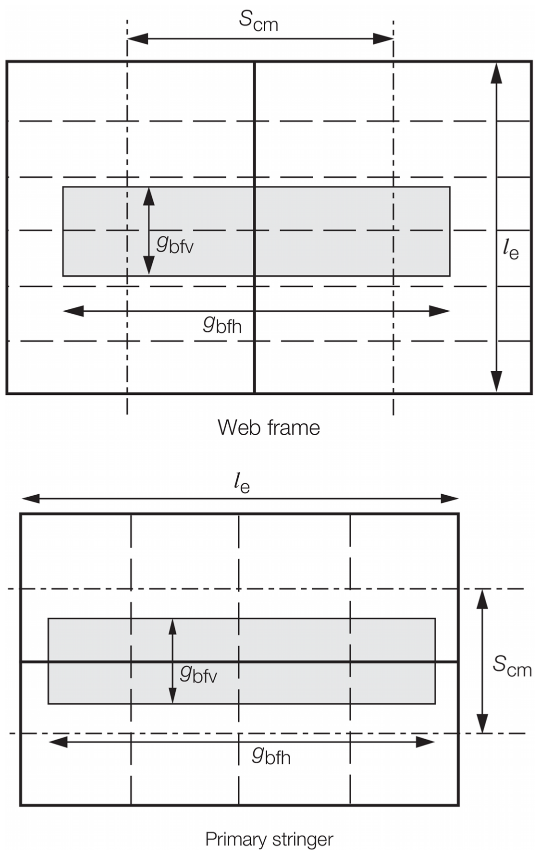


Figure 3.15.2 Mean spacing between primary members, S_{cm} and the extents of the bow flare wave impact pressure, g_{bfh} and g_{bfv}

15.2.5 The scantlings of secondary stiffeners are not to be less than:

(a) Effective plastic section modulus of stiffeners:

$$Z_p = 3,75 h_s s_{cm} k_s l^2_e \times 10^{-3} \text{ cm}^3$$

where

h_s = wave impact head, in metres, as defined in *Vol 1, Pt 6, Ch 3, 15.2 Strengthening against bow flare wave impacts 15.2.2*

s_{cm} = mean spacing of secondary stiffeners, in mm, measured along a chord between parallel adjacent members or equivalent supports, as shown in *Figure 3.15.1 Chord spacing and mean chord spacing for secondary members*

Other symbols are as defined in *Vol 1, Pt 6, Ch 3, 15.2 Strengthening against bow flare wave impacts 15.2.3* and *Vol 1, Pt 6, Ch 3, 15.2 Strengthening against bow flare wave impacts 15.2.4*

(b) Web area of secondary stiffeners

$$A = 3,7 s_{\text{cm}} k_{\text{s}} h_{\text{s}} \left(l_{\text{e}} - \frac{s_{\text{cm}}}{2000} \right) \times 10^{-4} \text{ cm}^2$$

where

s_{cm} = mean spacing of secondary stiffeners, in mm, measured along a chord between parallel adjacent members or equivalent supports, as shown in *Figure 3.15.1 Chord spacing and mean chord spacing for secondary members*

h_s = bow flare wave impact head, in metres, as defined in *Vol 1, Pt 6, Ch 3, 15.2 Strengthening against bow flare wave impacts 15.2.2*

Other symbols are as defined in *Vol 1, Pt 6, Ch 2, 1 General*.

15.2.6 The effective section properties of secondary stiffeners are to be taken as:

(a) Plastic section modulus of secondary stiffeners, Z_p is to be taken as:

$$Z_p = (2,8 \times 10^{-4} s_{cm} t_p^{\ 2}) - (10^{-3} b_f b_{fc} t_f \sin\theta_e) + (5 \times 10^{-4} (h_w^{\ 2} t_w + 2 b_f t_f h_w) \cos\theta_e) \text{ cm}^3$$

where

θ_e = $C_o (90 - \phi)$

C_o = 1,1

ϕ = the angle between the stiffener and the side shell, in degrees

b_{fc} = $0,5(b_f - t_w)$ for L profiles

= 0 for flat bar and T profiles

= *see Figure 2.2.1 Dimensions of longitudinals* in Chapter 2, for bulb profiles

h_w = height of web, in mm

t_w = web thickness, in mm

b_f = breadth of flange, in mm

t_f = flange thickness, in mm

t_p = thickness of attached plating, in mm

s_{cm} = defined in *Vol 1, Pt 6, Ch 3, 15.2 Strengthening against bow flare wave impacts 15.2.5*.

(b) Web area of secondary stiffeners, A_s is to be taken as:

$$A_s = 0,01 (h_w + t_p) t_w \sin\phi \text{ cm}^2$$

15.2.7 For primary members with cut-outs for the passage of secondary stiffeners, and which may have web stiffeners connected to the secondary stiffener, buckling checks are to be carried out to ensure that the primary member web plating and web stiffener will not buckle under the design load. The buckling procedure to be followed is given in *Table 3.15.1 Buckling procedure for primary member web plating and web stiffener* Where the web stiffener is fitted with a bracket, the buckling capability of the web stiffener in way of the cut-out is to take into account the bracket. Where no web stiffener is fitted, the buckling capability of the primary member web plating is to be checked for the total load transmitted to the connection.

15.2.8 The structural scantlings required in areas strengthened against bow flare wave impact are to be tapered to meet the normal shell envelope requirements.

15.2.9 Where the stiffener web is not perpendicular to the plating, tripping brackets may need to be fitted in order to obtain adequate lateral stability.

15.2.10 Where the angle between the primary structure web and the plating is less than 70°, the effective section modulus and shear area are to take account of the non-perpendicularity.

15.2.11 The side structure scantlings required by this Section must in no case be taken less than those required by other Sections of *Vol 1, Pt 6, Ch 3 Scantling Determination*

15.3 Strengthening against wave impact loads

15.3.1 The requirements of *Vol 1, Pt 6, Ch 3, 15.2 Strengthening against bow flare wave impacts* are to be applied to areas of plating which are liable to be subjected to wave impact loads; for example, bottom plating of wide transom sterns, undersides of sponsons for aircraft lifts.

Table 3.15.1 Buckling procedure for primary member web plating and web stiffener

Steps	Members	
	Primary member web plating	Primary member web stiffener
Determination of the design compressive stress, σ_a, N/mm^2 (kgf/mm^2)	$\sigma_a = \dfrac{1000P_w}{A_w}$	$\sigma_a = \dfrac{1000P_s}{A_s}$
Determination of the elastic critical buckling stress, σ_e, in compression, N/mm^2 (kgf/mm^2)	$\sigma_e = \dfrac{9,87EI_W}{l_w A_w^2}$	$\sigma_e = \dfrac{9,87EI_S}{l_s A_s^2}$
Determination of the corrected critical buckling stress, σ_{cr}, in compression, N/mm^2 (kgf/mm^2)	$\sigma_{cr} = \sigma_0 \left(1 - \dfrac{\sigma_0}{\sigma_e}\right)$ $\sigma_{cr} = \sigma_e$	where $\sigma_e > \dfrac{\sigma_0}{2}$ where $\sigma_e \leq \dfrac{\sigma_0}{2}$
Requirement	$\sigma_{cr} \geq \sigma_a$	

Symbols

b_w, b_s, l_w and l_s are dimensions, in mm, as shown in *Figure 3.15.3 Dimensions of critical areas of (a) primary member web plating and (b) primary member web stiffener*

h_s = equivalent bow flare slamming head, in metres, as defined in *Vol 1, Pt 6, Ch 3, 15.2 Strengthening against bow flare wave impacts 15.2.2*

s_{cm} = mean spacing of secondary stiffeners, in mm, as defined in *Vol 1, Pt 6, Ch 3, 15.2 Strengthening against bow flare wave impacts 15.2.4*

t_s = thickness of primary member web stiffener, in mm

t_w = thickness of primary member web plating, in mm

A_w = $b_W t_W$ mm^2

A_s = $b_S t_S$ mm^2

E = modulus of elasticity, in N/mm^2

= 206000 N/mm^2 for steel

I_s = $\dfrac{b_s t_s^3}{12}$ mm^4

I_w = $\dfrac{b_w t_w^3}{12}$ mm^4

P = total load transmitted to the connection

= $10{,}06\, S_{cm}\, s_{cm}\, h_s \times 10^{-3}$ kN

P_s = load transmitted through the primary member web stiffener, in kN, to be determined from $P_2 = P - P_1$, in kN, or by direct calculations. Where P_1 = pressure transmitted through collar arrangement and P = total load transmitted to the primary member

P_w = load transmitted through the primary member web plating, in kN

= $P - P_s$, or by direct calculations

S_{cm} = mean spacing of primary members, in metres, as defined in *Vol 1, Pt 6, Ch 3, 15.2 Strengthening against bow flare wave impacts 15.2.5*

σ_o = specified minimum yield stress, in N/mm^2

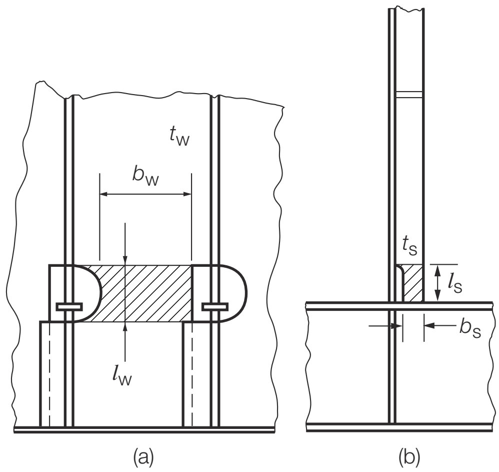


Figure 3.15.3 Dimensions of critical areas of (a) primary member web plating and (b) primary member web stiffener

Section 16
Masts

16.1 General

16.1.1 This Section may be used to determine the required scantlings for stayed or unstayed single masts of conventional design on NS1, NS2 and NS3 type ships. Additional requirements for masts are given in *Vol 1, Pt 4, Ch 1, 5.3 Masts and externally mounted sensors or equipment*.

16.2 Pole masts

16.2.1 The maximum allowable combined bending and direct stress in pole masts is not to exceed the value given in *Table 3.16.1 Allowable stresses in masts*. The maximum allowable shear stress is not to exceed 0,58 times the value given in *Table 3.16.1 Allowable stresses in masts*.

Table 3.16.1 Allowable stresses in masts

	Item	Allowable stress, in N/mm^2
(1)	Stayed mast:	$0,50\sigma_y$
(2)	Unstayed mast:	$0,55\sigma_y$
(3)	Cross trees, outriggers, etc:	$0,55\sigma_y$

16.2.2 The forces acting on the mast are to be calculated in accordance with *Vol 1, Pt 5, Ch 3, 6.4 Loads for masts*.

16.3 Unstayed masts

16.3.1 The total stress (σ_t) at any particular location is to be taken as:

$$\sigma_t = [(\sigma_b + \sigma_c)\ 2 + 3q\ ^2]\ \frac{1}{2}\ \text{N/mm}^2$$

where

σ_b = the bending stress at that location due to the bending moments acting on the mast

σ_c = the direct compressive stress at that location due to the vertical components of force. In general, the weight of the mast and cross trees may be ignored in this calculation

q = the shear stress due to torque in the mast. The effect of torque need only be considered where cross trees are fitted.

16.3.2 The total stress is to be determined at each change of plate thickness or other change of section along the mast. It is recommended that a plot or table of stress to a base of mast length be prepared.

16.4 Stayed masts

16.4.1 In the absence of stays the mast will deflect under the influence of the imposed forces. Where stays are fitted they will extend under tension, the amount of elongation being related to the deflection of the mast at the point of attachment of the stays. The distribution of forces in the mast and stays may therefore be obtained by consideration of:

(a) The equilibrium between the deflection of the mast and the corresponding elongations of the stays.
(b) The equilibrium between the imposed loads on the mast and the reactions in the mast and the stays.

16.4.2 These calculations are to be made using appropriately defined co-ordinate axes. Attention is drawn to the importance of assigning the correct sign to the angles and dimensions used. Any stay which would be required to work in compression is to be ignored.

16.4.3 Elongation of the stays is to be calculated on the basis of the area enclosed by a circle of diameter equal to the nominal diameter of the rope in association with an effective modulus of elasticity of 61300 N/mm^2 (6250 kgf/mm^2). Consideration will, however, be given to the use of a higher modulus of elasticity where this is demonstrated by suitable tests to be applicable.

16.4.4 The total stress in the mast at any particular location is to be determined. Attention is drawn to the fact that increased stiffness of the mast leads to a rapid increase in stress in the mast with a corresponding reduction in the effectiveness of the stays. It is desirable, therefore, to design the mast for the required section modulus in association with the least practicable moment of inertia.

16.4.5 Wire rope stays are to be in one length and their construction is to comply with the requirements of *Ch 8 Fittings, Loose Gear and Ropes* of the *Code for Lifting Appliances in a Marine Environment* (LAME).

16.4.6 The scantlings of a stay are to be such as to provide the tensile force and elongation to meet these requirements. The breaking load of a stay is to be not less than 3,5 times the maximum calculated force on that stay.

■ *Section 1* General

1.1 Application

1.1.1 The requirements for longitudinal and transverse global strength are contained within this Chapter.

1.1.2 This Chapter contains Sections detailing the analysis requirements for the following topics:

- Hull girder strength.
- Extreme strength assessment.
- Residual strength assessment

1.1.3 **Section 2, Hull girder strength.** This Section specifies the hull girder strength requirements based on the conventional elastic design and buckling analyses. All ships are to comply fully with the requirements of this Section.

1.1.4 **Section 3, Extreme strength assessment.** This Section specifies the requirements for the assessment of the extreme hull girder strength to withstand wave loads that have a low probability of occurring during the life of the ship. This is an optional assessment and ships which comply with the extreme strength requirements can apply for the notation **ESA1** or **ESA2**, *see Vol 1, Pt 1, Ch 2, 3.7 Hull strength notations 3.7.1*

1.1.5 **Section 4, Residual strength assessment.** This Section specifies the requirements for the assessment of the residual hull girder strength after the ship has sustained structural damage. This is an optional assessment and ships which comply with the residual strength requirements can apply for the notation **RSA1**, **RSA2** or **RSA3**, *see Vol 1, Pt 1, Ch 2, 3.7 Hull strength notations 3.7.1*.

1.2 Hull girder strength notations

1.2.1 The following notations are available for all ships with regard to global hull girder strength aspects:

- **ESA1, ESA2** Extreme strength assessment.
- **RSA1, RSA2, RSA3** Residual strength assessment.

A distinction is made between levels of performance and levels of assessment; the numeral in the notation reflects the level of assessment. Levels of performance are denoted by the letters A, B, C for collision or grounding damage and numerals I, II and III for damage from military threats and are confidential to the Owner. *See Vol 1, Pt 6, Ch 4, 4.2 Extent of damage and analysis* for non-military threats and *Vol 1, Pt 4, Ch 2, 7 Residual strength* for military threats.

1.2.2 The performance of the ship with respect to extreme hull girder strength aspects may be evaluated at two levels. **ESA1**, the lowest level offers a basic assessment of the ship's capability. **ESA2**, the higher level is a much more rigorous assessment of the hull's capability to withstand extreme sea states.

1.2.3 It is recommended that ships of groups NS1 and NS2 should comply with **ESA1**. However, it is the responsibility of the Owner to specify the level of extreme strength assessment required.

1.2.4 The extreme strength assessment level adopted must reflect the performance level required by other notations.

1.2.5 The two levels of assessment available for the extreme strength assessment notation are summarised as follows:

ESA1 = This uses elastic theory, based on the section moduli and area, and determination of the buckling strength to resist the global hull girder loads. The assessment is to be made at a minimum of three locations.

ESA2 = Uses a '2D' ultimate strength beam representation and a failure level criterion based on the section ultimate bending moments being satisfactory compared to the design bending moments in both hogging and sagging. This will require assessment using ultimate strength calculations at all critical longitudinal locations.

1.2.6 The performance of the ship with respect to residual strength aspects may be evaluated at several levels. The lowest level offers a basic assessment of the ship's capability to survive. Higher residual strength levels are designed to show that the ship has an improved performance with respect to hull's capability to withstand increased damage extents and scenarios.

1.2.7 Three assessment and performance levels are available for the residual strength assessment notation. **RSA1**, the assessment Level 1 residual strength assessment, and performance level A are recommended as a minimum for all ships of groups **NS1** and **NS2**. However, it is the responsibility of the Owner to specify the level of residual strength assessment required.

1.2.8 The residual strength assessment level adopted must reflect the performance level required by other notations.

1.2.9 The three levels of assessment available for the extreme strength assessment notation are summarised as follows:

RSA1 = This uses elastic theory, based on the remaining section moduli and area after damage, and determination of the buckling strength to resist the global hull girder loads. The assessment is to be made at a minimum of three critical sections.

RSA2 = Uses a '2D' ultimate strength beam representation and a failure level criterion based on the section ultimate bending moments being satisfactorily compared to the design bending moments in both hogging and sagging. The assessment is to be made at a minimum of three critical sections.

RSA3 = Uses a '3D' definition of a section of the hull girder and relies on geometric and material failure criteria implicit in the chosen finite element code. It could also include coupled Euler-Lagrange formulations to specifically account for internal and external blast effects, UNDEX shock and whipping.

1.3 Symbols and definitions

1.3.1 The symbols and definitions applicable to this Chapter are defined below or in the appropriate sub-Section.

L_R = Rule length of the ship, in metres

B = moulded breadth of ship, *see Vol 1, Pt 3, Ch 1, 5.2 Principal particulars* in metres

σ_0 = specified minimum yield strength of the material, in N/mm^2

τ_0 = $\sigma_0/\sqrt{3}$

f_{hts} = higher tensile steel correction factor, *see Table 5.1.1 High tensile steel stress correction factor f hts*

1.3.2 The strength deck is to be taken as follows:

(a) Where there is a complete upper deck, the strength deck is the upper deck.

(b) Where the upper deck is stepped, as in the case of ships with a raised quarterdeck, the strength deck is stepped as shown in *Figure 4.1.1 Strength deck* Adequate provision should be made for the transfer of load between the stepped decks. The length of overlap required is to be taken as 4 times the deck height.

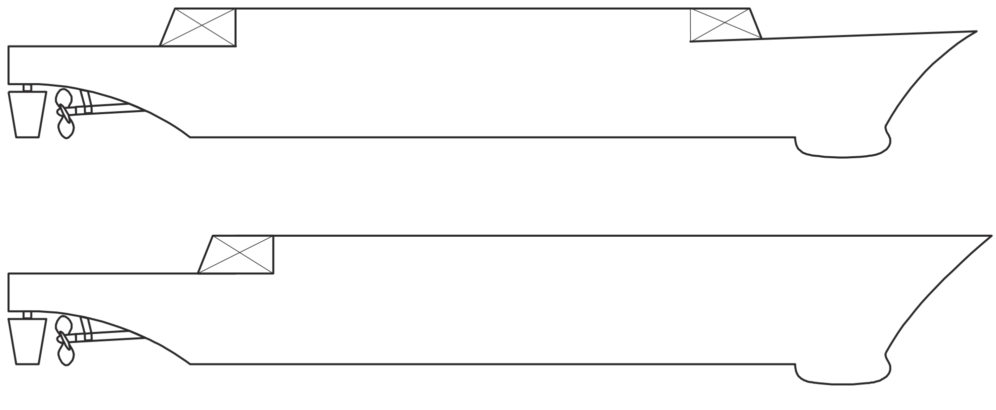


Figure 4.1.1 Strength deck

1.4 Calculation of hull section modulus

1.4.1 In general, the effective sectional area of continuous longitudinal strength members, after deduction of openings, is to be used for the calculation of midship section modulus.

1.4.2 Structural members which contribute to the overall hull girder strength are to be carefully aligned so as to avoid discontinuities resulting in abrupt variations of stresses and are to be kept clear of any form of openings which may affect their structural performances.

1.4.3 In general, short superstructures or deckhouses will not be accepted as contributing to the global longitudinal or transverse strength of the ship. However, where it is proposed to include substantial, continuous stiffening members, special consideration will be given to their inclusion on submission of the designer's/builder's calculations, *see also Vol 1, Pt 6, Ch 4, 2.5 Superstructures global strength*

1.4.4 Where continuous deck longitudinals or deck girders are arranged above the strength deck, special consideration may be given to the inclusion of their sectional area in the calculation of the hull section modulus, *Z*. The lever is to be taken to a position corresponding to the height of the longitudinal member above the moulded deck line at side amidships. Each such case will be individually considered.

1.4.5 Adequate transition arrangements are to be fitted at the ends of effective continuous longitudinal strength members in the deck and bottom structures.

1.4.6 Scantlings of all continuous longitudinal members of the hull girder based on the minimum section stiffness requirements determined from 2.2 are to be maintained within $0,4L_R$ amidships. However, in special cases, based on consideration of type of ship, hull form and loading conditions, the scantlings may be gradually reduced towards the ends of the $0,4L_R$ part, bearing in mind the desire not to inhibit the ship's loading and operational flexibility.

1.4.7 Structural material which is longitudinally continuous but which is not considered to be fully effective for longitudinal strength purposes will need to be specially considered. The global longitudinal strength assessment must take into account the presence of such material when it can be considered effective. The consequences of failure of such structural material and subsequent redistribution of stresses into or additional loads imposed on the remaining structure must be considered.

1.4.8 In particular, all longitudinally continuous material will be fully effective in tension whereas this may be not be so in compression due to a low buckling capability. In this case, it may be necessary to derive and apply different hull girder section moduli to the hogging and sagging bending moment cases.

1.4.9 Openings in decks, longitudinal bulkheads and other longitudinal effective material having a length in the fore and aft directions exceeding 0,1*B* m or 2,5 m or a breadth exceeding 1,2 m or 0,04*B* m, whichever is the lesser, are in all cases to be deducted from the sectional areas used in the section modulus calculation.

1.4.10 Openings smaller than stated in *Vol 1, Pt 6, Ch 4, 1.4 Calculation of hull section modulus 1.4.9*, including manholes, need not be deducted provided they are isolated and the sum of their breadths or shadow area breadths, *see Vol 1, Pt 6, Ch 4, 1.4 Calculation of hull section modulus 1.4.13*, in one transverse section does reduce the section modulus at deck or bottom by more than 3 per cent.

1.4.11 The expression 0,06 ($B_1 - \Sigma b_1$), where B_1 equals the breadth of the ship at the section considered and Σb_1 equals the sum of breadths of deductible openings, may be used for deck openings in lieu of the 3 per cent limitation of reduction of section modulus in *Vol 1, Pt 6, Ch 4, 1.4 Calculation of hull section modulus 1.4.10*.

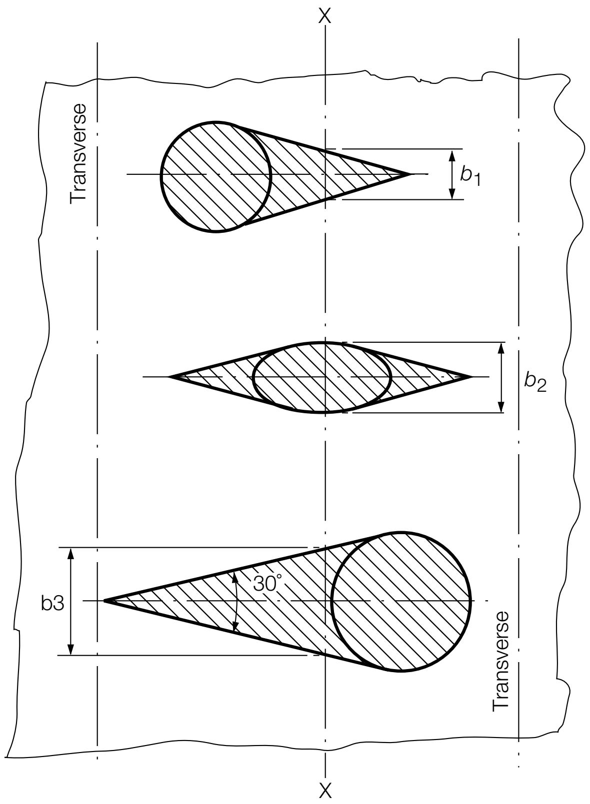


Figure 4.1.2 Isolated openings

1.4.12 Where a large number of openings are proposed in any transverse space, special consideration will be required.

1.4.13 Where calculating deduction-free openings, the openings are assumed to have longitudinal extensions as shown by the shaded areas in *Figure 4.1.2 Isolated openings* The shadow area is obtained by drawing two tangent lines to an opening angle of 30°. The section to be considered is to be perpendicular to the centreline of the ship and is to result in the maximum deduction in each transverse space.

1.4.14 Isolated openings in longitudinals or longitudinal girders need not be deducted if their depth does not exceed 25 per cent of the web depth or 75 mm, whichever is the lesser.

1.4.15 Openings are considered isolated if they are spaced more than 1 m apart.

1.4.16 A reduction for drainage holes and scallops in beams and girders, etc. is not necessary so long as the global section modulus at deck or keel is reduced by no more than 0,5 per cent.

1.5 General

1.5.1 The Level 1 assessment procedures specified in Lloyd's Register's (hereinafter referred to as 'LR') Structural Detail Design Guide for fatigue design assessment, **FDA**, are to be generally applied to the construction details of all ships.

1.6 Direct calculations

1.6.1 Direct calculations using finite element analysis may be necessary for ships with complicated longitudinal structural arrangements such as ships:

- of novel design;

- with significant discontinuous longitudinal material;
- with large deck openings, or where warping stresses in excess of 14,7 N/mm^2 are likely to occur;
- with large openings in the side shell, especially in way of the sheerstrake.

■ *Section 2*
Hull girder strength

2.1 General

2.1.1 Longitudinal strength calculations are to be submitted for all ships with a Rule length, L_R, exceeding 50 m and are to cover the range of operating conditions proposed in order to determine the required hull girder strength. The still water, wave and dynamic bending moments and shear forces are to be calculated in accordance with the requirements of *Vol 1, Pt 5, Ch 4 Global Design Loads*

2.1.2 For ships of ordinary hull form with a Rule length, L_R, less than 50 m, the minimum hull girder strength requirements are generally satisfied by scantlings obtained from local strength requirements. However, longitudinal strength calculations may be required by LR, dependent upon the form, constructional arrangement and proposed loading.

2.2 Bending strength

2.2.1 The effective geometric properties of all critical transverse sections along the length of the ship are to be calculated directly from the dimensions of the section using only effective material elements which contribute to the global longitudinal strength irrespective of the grades of steel incorporated in the construction, *see Vol 1, Pt 6, Ch 4, 1.4 Calculation of hull section modulus*

2.2.2 Where higher tensile is fitted to satisfy global strength requirements, the extent of higher tensile steel is to be as specified in *Vol 1, Pt 6, Ch 2, 1.6 Higher tensile steel 1.6.3* Where a mix of steel grades is used for plating and associated stiffeners, then the lower of the steel grades is to be used for the derivation of the permissible stresses, *see* 2.2.3.

2.2.3 The longitudinal strength of the ship is to satisfy the following criteria for the hogging and sagging conditions:

$$\sigma_{\mathrm{B}} < \sigma_{\mathrm{p}}$$

$$\sigma_{\mathrm{D}} < \sigma_{\mathrm{P}}$$

$$\sigma_{\mathrm{ws}} < f_{\sigma\,\mathrm{ws}}\,\sigma_{0(\mathrm{MS})}$$

where

σ_p = maximum permissible hull vertical bending stress, in N/mm^2

σ_p = $f_{\sigma hg}\, f_{hts}\, \sigma_o$

$f_{\sigma hg}$ = limiting hull bending stress coefficient, derived as follows:

= (i) from $0,3L_R$ to $0,7L_R$

$f_{\sigma hg} = 0,75$

(ii) for continuous longitudinal structural members aft of $0,3L_R$ and forward of $0,7L_R$

$f_{\sigma hg} = 0,319 + 2,311\, x/L_R - 2,974\,(x/L_R)^2$

where

x = the distance, in metres, from the F.P. for locations within the forward end of L_R and from the A.P. for locations within the aft end of L_R

$f_{\sigma ws}$ = 1,2, limiting working stress coefficient

= NOTE, the σ_{ws} criterion may be relaxed if it can be demonstrated that either:

(i) a continuous fatigue control monitoring system is to be adopted for the in-service life of the ship

(ii) a fatigue design assessment procedure is applied which demonstrates that a higher limiting working stress coefficient, $f_{\sigma ws}$, may be applied

$\sigma_{o\,(MS)}$ = specified yield stress, in N/mm^2, for mild steel

σ_B, σ_D and σ_{ws} are given in *Table 4.2.1 Longitudinal component stresses*

f_{hts} and σ_o are defined in *Vol 1, Pt 6, Ch 4, 1.3 Symbols and definitions 1.3.1*

Table 4.2.1 Longitudinal component stresses

Component stress type	Nominal stress (N/mm^2)
Hull girder bending stress at strength deck, *see* Note 1	$\sigma_D = \dfrac{M_R}{1000 Z_D}$
Hull girder bending stress at keel, *see* Note 1	$\sigma_B = \dfrac{M_R}{1000 Z_B}$
Hull girder bending stress range, *see* Note 2	$\sigma_{ws} = \dfrac{M_{WHog} - M_{WSag}}{1000 Z_D}$
Symbols	
M_R = Rule bending moment, in kNm, given in *Vol 1, Pt 5, Ch 4, 3.10 Hull girder design loads* M_{WHog} = hogging value of M_W, in kNm, given in *Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments* M_{WSag} = sagging value of M_W, in kNm, given in *Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments* Z_D = actual section modulus at deck, in m^3 Z_B = actual section modulus at keel, in m^3	
Note 1. The hogging and sagging bending moments are to be considered. Note 2. The stress range at the keel or other longitudinally effective material should be used if it is greater than the stress range at the strength deck.	

2.2.4 Special consideration will be given to increasing the permissible stress outside 0,3L_R to 0,7L_R provided that sufficient buckling checks are carried out.

2.2.5 The requirements for ships of special or unusual design and for special operations will be individually considered.

2.2.6 Where different grades of steel are used then it should be ensured that the design stress in each structural member is less than the permissible hull vertical bending stress, i.e.

$$\sigma_{hg} < \sigma_p$$

where

σ_{hg} = is given in *Vol 1, Pt 6, Ch 4, 2.2 Bending strength 2.2.7*

σ_p = is given in *Vol 1, Pt 6, Ch 4, 2.2 Bending strength 2.2.3*

2.2.7 The design stress due to hull girder bending, σ_{hg}, for each structural member is given by

$$\sigma_{hg} = \left(\frac{M_R}{1000Z_i}\right) \text{N/mm}^2$$

where

Z_i = actual section modulus at structural element being considered, in m^3

M_R is given in *Table 4.2.1 Longitudinal component stresses*.

2.3 Shear strength

2.3.1 The shear strength of the all ships is to satisfy the requirements given in this Section.

2.3.2 For ships with large openings in the side shell and/or a complex arrangement of longitudinal bulkheads and decks is proposed, shear flow calculations or direct calculation may be required.

2.3.3 Where shear flow calculation procedures other than those available within ShipRight are employed, the requirements of *Vol 1, Pt 6, Ch 3, 14 Strengthening for bottom slamming* are to be complied with.

2.3.4 The assessment of still water shear stresses is to take into consideration the effectiveness of the following:

- continuous superstructures;
- the sizes and arrangements of window and door openings;
- access openings or cut-outs in side shell, longitudinal bulkheads, etc.

2.3.5 The shear strength of the ship at any position along the length is to satisfy the following criterion:

$$\frac{|\,Q_R\,|\,A_Z}{I\,\delta_o} \leq \tau_p$$

where

δ_o is to be taken as the minimum value of δ_i, and

τ_p = maximum permissible shear stress, in N/mm^2

= $f_{\tau hg}\,\tau_o$

$f_{\tau hg}$ = 0,75f_{hts}, limiting hull shear stress coefficient

Q_R = Rule shear force, in kN, determined from *Vol 1, Pt 5, Ch 4, 3.10 Hull girder design loads*

I = the inertia of the hull about the transverse neutral axis at the section concerned, in m^4

A_z = the first moment of area of the longitudinal members about the neutral axis, in m^3

Only longitudinally effective members that lie between the vertical level being considered and the vertical extremity are to be included

δ_i = $\dfrac{t_i}{k_i}$

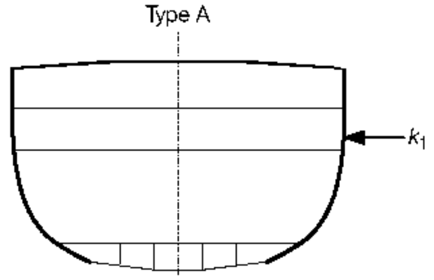
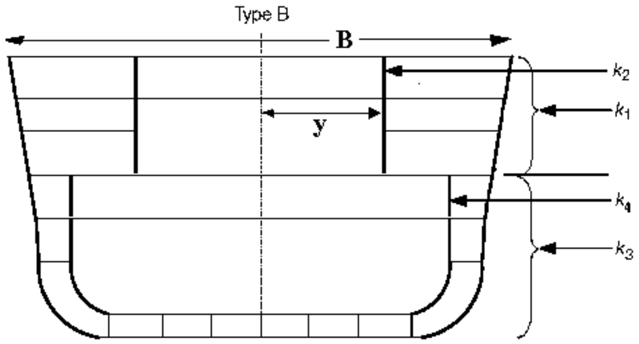
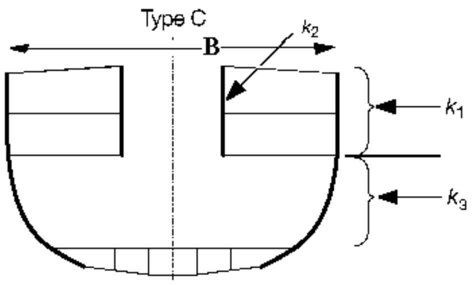
i = structural member index for the hull configuration under consideration, *see Table 4.2.2 k_i factors*

t_i = the plate thickness of the structural member at the vertical level and section under consideration, in mm

k_i = factors determined from *Table 4.2.2 k_i factors* for the hull configuration under consideration

f_{hts} and τ_o are defined in *Vol 1, Pt 6, Ch 4, 1.3 Symbols and definitions 1.3.1*.

Table 4.2.2 k_i factors

<table>
<tr><th>Hull configuration</th><th>k_i factors</th></tr>
<tr><td>
</td><td>Member 1
$k_1 = 0,5$</td></tr>
<tr><td>
</td><td>Member 1
$k_1 = 0,04\frac{A_1}{A_2} + 0,2\left(\frac{y}{B} - 0,19\right) + 0,25$
Member 2
$k_2 = -0,04\frac{A_1}{A_2} - 0,2\left(\frac{y}{B} - 0,19\right) + 0,25$
Member 3
$k_3 = -0,01\frac{A_3}{A_4} + 0,25$
Member 4
$k_4 = 0,01\frac{A_3}{A_4} + 0,25$</td></tr>
<tr><td>
</td><td>Member 1
$k_1 = 0,04\frac{A_1}{A_2} + 0,2\left(\frac{y}{B} - 0,19\right) + 0,25$
Member 2
$k_2 = -0,04\frac{A_1}{A_2} - 0,2\left(\frac{y}{B} - 0,19\right) + 0,25$
Member 3
$k_3 = 0,5$</td></tr>
</table>

Symbols
Note i = structural index for different hull configurations Note = 1 or 3, the side shell at the section under consideration Note = 2 or 4, the longitudinal bulkheads at the section of consideration Note A_T = half the total effective shear area at the section under consideration, in cm^2, $A_T = A_i$ Note A_i = the area of structural member i at the section under consideration, in cm^2 Note In the event of part of the structural member being non-vertical A_i is to be calculated using the projected area in the vertical direction, *see Figure 4.2.2 Calculation of Ai for non vertical parts of structural members (referenced from Table 4.2.2)* Note *y* is the distance of structural member 2 from the centreline Note *B* is given in *Vol 1, Pt 6, Ch 4, 1.3 Symbols and definitions 1.3.1*
Note 1. For hull configurations not included above, k_i factors are to be specially considered. Note 2. Where it is necessary to increase the thickness of the side shell or longitudinal bulkhead(s) to meet these requirements, the original thicknesses are to be used in the calculation of the cross-sectional areas A_i.

2.3.6 The design shear stress for each structural member, τ_{hg}, due to hull girder shear forces is given by

$$\tau_{hg} = \frac{|\,Q_R\,|\,A_Z}{I\,\delta_i}$$

where

Q_R, A_Z, I and δ_i are given in *Vol 1, Pt 6, Ch 4, 2.3 Shear strength 2.3.5*

2.3.7 Where a plate is tapered, the permissible combined shear stress is not to be exceeded at any point in way of the taper, *see Figure 4.2.1 Tapered plates*

2.4 Torsional strength

2.4.1 Torsional stresses are typically small for mono-hulls of ordinary form and can generally be ignored.

2.4.2 The calculation of torsional stresses and/or deflections may be required when considering ships with large deck openings, unusual form or proportions, or special operating modes which induce significant torsional stresses. Calculations may in general be required to be carried out using direct calculation procedures. Such calculations are to be submitted in accordance with *Vol 1, Pt 6, Ch 4, 1.5 General*

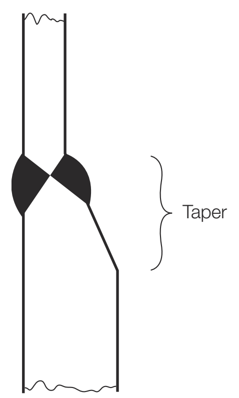


Figure 4.2.1 Tapered plates

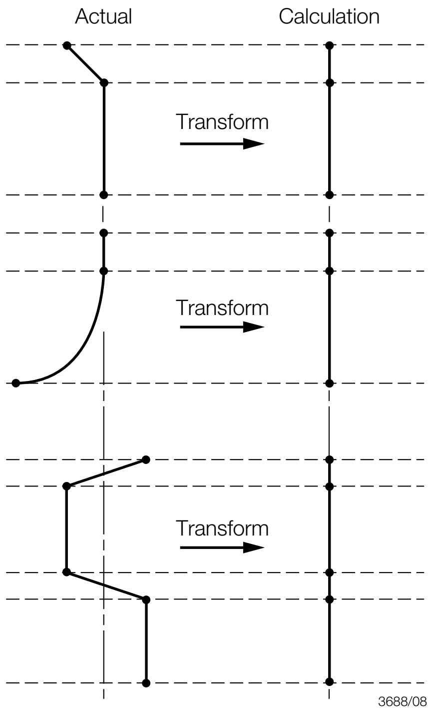


Figure 4.2.2 Calculation of A_i for non vertical parts of structural members (referenced from Table 4.2.2)

2.5 Superstructures global strength

2.5.1 The effectiveness of the superstructure in absorbing hull girder bending loads is to be established where the first tier of the superstructure extends within 0,4L_R amidships and where:

$l_1 > b_1 + 3h_1$

where

l_1 = length of first tier, in metres

b_1 = breadth of first tier, in metres

h_1 = ‘tween deck height of first tier, in metres

2.5.2 For superstructures with one or two tiers extending outboard to the ship’s side shell, the effectiveness in absorbing hull girder bending loads in the uppermost effective tier may be assessed by the following factor:

$$\eta_S = 7\,((\varepsilon - 5)\,\gamma^4 + 94\,(5 - \varepsilon)\,\gamma^3 + 2800\,(\varepsilon - 5{,}8)\,\gamma^2 + 27660\,(9 - \varepsilon)\,\gamma)\,f(\lambda, \mathrm{N}) \times 10^{-7}$$

(a) where

$f\,(1, \mathrm{N} = 1) = 1$

$f\,(\lambda, \mathrm{N} = 2) = 0{,}90\lambda^3 - 2{,}17\lambda^2 + 1{,}73\lambda + 0{,}50$

and

N = 1 if $l_2 < 0{,}7\,l_1$

= 2 if $l_2 \geq 0{,}7\,l_1$

$\lambda = \dfrac{l_{\mathrm{W}}}{L_{\mathrm{R}}}$ or 1, whichever is less

$\varepsilon = \dfrac{b_1}{h_1}$ or 5, whichever is less

$\gamma = \dfrac{l_{\mathrm{w}}}{h_1}$ or 25, whichever is less

$l_{\mathrm{W}} = l_1$ for N = 1

$= (2\,l_1 + l_2)/3$ for N = 2

L_{R} is defined in *Vol 1, Pt 6, Ch 4, 1.2 Hull girder strength notations 1.2.1*, in metres

l_1, b_1, h_1 are defined in *Vol 1, Pt 6, Ch 4, 2.5 Superstructures global strength 2.5.1*, in metres.

l_2 = length of second tier, in metres.

2.5.3 The design stress due to hull girder bending, σ_{hg}, in the uppermost effective tier at side may be derived according to the following formula:

$$\sigma_{\mathrm{hg}} = \frac{\eta_{\mathrm{s}} M_R}{1000 Z_s} \ \mathrm{N/mm^2}$$

where

M_{R} = hull girder bending moment at amidships due to sagging as determined in *Vol 1, Pt 5, Ch 4, 5 Residual strength hull girder loads*, in kNm

Z_{s} = section modulus at the structural element being considered, in m^3. The section modulus is to include the superstructure tiers, assuming the tiers to be η_{s} effective.

η_{s} = as defined in *Vol 1, Pt 6, Ch 4, 2.5 Superstructures global strength 2.5.2*

2.5.4 The stresses in the superstructure decks and sides are to be checked against buckling in accordance with *Vol 1, Pt 6, Ch 4, 2.6 Buckling strength* These stresses should also comply with the stress criteria in *Vol 1, Pt 6, Ch 4, 2.2 Bending strength 2.2.3*

2.5.5 The uppermost effective tier may need to fulfil the requirements for strength deck when the following applies:

$$\eta_{\mathrm{s}} > \left(1 + \frac{Z_0 h}{I_{100}}\right)^{-1}$$

where

η_{s} is defined in *Vol 1, Pt 6, Ch 4, 2.5 Superstructures global strength 2.5.2*

Z_0 = section modulus of hull only at hull upper deck, in m^3

I_{100} = moment of inertia of hull and effective tiers, assuming tiers to be 100 per cent effective, in m^4

h = height from hull upper deck to uppermost effective tier, in metres.

2.6 Buckling strength

2.6.1 The buckling requirements in *Vol 1, Pt 6, Ch 2, 3 Buckling* are to be applied to plate panels and longitudinals subject to hull girder compression and shear stresses. The design stresses are to be based on the design values of still water and wave bending moments and shear forces and are given in *Vol 1, Pt 6, Ch 4, 2.2 Bending strength 2.2.4* and *Vol 1, Pt 6, Ch 4, 2.3 Shear strength 2.3.6* The design factors of safety are given in *Vol 1, Pt 6, Ch 5 Structural Design Factors*

2.6.2 When a Level 2 extreme strength assessment is applied, the Owner may specify in the tailoring document that the buckling assessment of plate panels subject to compressive stresses is not required. In this case the buckling requirements of *Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements* may be relaxed. The requirements of *Vol 1, Pt 6, Ch 2, 3.6 Shear buckling of stiffened panels* for shear buckling and the remainder of *Vol 1, Pt 6, Ch 2, 3 Buckling* must always be complied with.

■ *Section 3*
Extreme Strength Assessment, ESA

3.1 General

3.1.1 The extreme hull girder strength of the ship is to be adequate to withstand wave loads that have a very low probability of occurring during the ship's service life at sea.

3.1.2 The Owner may specify that an extreme strength assessment is not required. In this case, the extreme strength **ESA1** or **ESA2** notation and all other notations which require the extreme strength notation will not be assigned.

3.1.3 The extreme strength capability of the ship to survive severe sea conditions can be assessed using fairly simple or more advanced analysis procedures. The level of complexity and thoroughness of the analysis procedure is reflected in the extreme strength assessment notation level assigned.

3.1.4 Two assessment levels are available for the extreme hull girder strength assessment notation. These are summarised below:

ESA1 – Level 1

- Extreme hull girder strength considered at a minimum of three longitudinal locations.
- Capability assessed using elastic analysis, limiting stress criteria and buckling factors of safety.

ESA2 – Level 2

- Extreme hull girder strength considered at all critical longitudinal locations.
- Capability assessed using elasto-plastic ultimate strength methods to determine extreme hull girder strength.

3.1.5 For the **ESA1** assessment, the extreme hull girder strength is to be verified using elastic theory, based on the actual section moduli and determination of the buckling strength to resist the global hull girder loads. The assessment criteria are given in *Vol 1, Pt 6, Ch 4, 3.3 Bending strength – Simplified assessment method ESA1* and *Vol 1, Pt 6, Ch 4, 3.4 Shear strength – Simplified assessment method ESA1* Alternatively the strength may be verified using ultimate strength methods.

3.1.6 For the **ESA2** assessment, the extreme hull girder strength is to be verified using ultimate strength methods based on non linear stress strain curves which include the stress strain relationship in the post buckling phase. The assessment criteria are given in *Vol 1, Pt 6, Ch 4, 3.5 Bending and shear strength – Ultimate strength analysis method ESA2*

3.2 Determination of critical sections

3.2.1 A critical section is defined as a transverse cross-section of the hull where the hull girder bending or shear section structural properties are lowest. Typically there will be critical sections in way of machinery spaces, large deck openings and at the ends of superstructure blocks.

3.2.2 The effective geometric properties of critical sections are to be calculated in accordance with *Vol 1, Pt 6, Ch 4, 2.2 Bending strength 2.2.1* and *Vol 1, Pt 6, Ch 4, 1.4 Calculation of hull section modulus* In defining the longitudinal position of each critical section, the shadow areas specified in *Vol 1, Pt 6, Ch 4, 1.4 Calculation of hull section modulus 1.4.13* are to be considered together with the proximity of other openings, *see Vol 1, Pt 6, Ch 4, 1.4 Calculation of hull section modulus 1.4.15*.

3.2.3 For the **ESA1** assessment, critical sections are to be considered at approximately the longitudinal positions $L_R/4$, $L_R/2$ and $3L_R/4$. Other longitudinal positions may also need to be considered depending on the structural arrangement of the ship.

3.2.4 For the **ESA2** assessment, critical sections are to be considered at all positions along the length. Typically it is expected that the local critical transverse section between adjacent main watertight bulkheads will be evaluated.

3.3 Bending strength – Simplified assessment method ESA1

3.3.1 If the simplified analysis method is adopted for extreme strength assessment, the longitudinal strength of the ship at each critical section is to satisfy the following criteria for the hogging and sagging conditions:

(a) $\sigma_{BEX} < \sigma_p$

(b) $\sigma_{DEX} < \sigma_p$

where

σ_p = is the maximum permissible hull vertical bending stress, in N/mm^2

= $f_{\sigma EX} \sigma_o$

$f_{\sigma EX}$ = 0,9, limiting hull bending stress coefficient

σ_{DEX} = is the extreme hull girder bending stress at strength deck

= $\dfrac{M_{REX}}{1000 Z_D}$

σ_{BEX} = is the extreme hull girder bending stress at keel

= $\dfrac{M_{REX}}{1000 Z_B}$

M_{REX} = extreme vertical wave and still water bending moment, in kNm, given in *Vol 1, Pt 5, Ch 4, 4.7 Extreme hull girder design loads*

Z_D = actual section modulus at deck, in m^3

Z_B = actual section modulus at keel, in m^3

f_{hts} and σ_o are defined in *Vol 1, Pt 6, Ch 4, 1.3 Symbols and definitions 1.3.1*.

3.3.2 The design extreme stress due to the extreme hull vertical bending moment, σ_{ex}, for each structural member is given by

$$\sigma_{ex} = \frac{M_{REX}}{1000 Z_i}$$

where

Z_i = actual section modulus at structural element being considered, in m^3

M_{REX} = is defined in *Vol 1, Pt 6, Ch 4, 3.3 Bending strength – Simplified assessment method ESA1 3.3.1*

3.3.3 It is not necessary to satisfy the plate panel buckling requirements for compressive stresses provided that shear buckling of plate panels and stiffened panels and all buckling modes of failure for longitudinal girders and stiffeners are satisfied. The design factors of safety are given in *Vol 1, Pt 6, Ch 5 Structural Design Factors*

3.3.4 Consequently, the following sections on buckling control are to be complied with, based on compressive stresses derived in accordance with *Vol 1, Pt 6, Ch 4, 3.3 Bending strength – Simplified assessment method ESA1 3.3.2*

(a) Secondary stiffening in direction of compression, *Vol 1, Pt 6, Ch 2, 3.7 Secondary stiffening in direction of compression*.

(b) Secondary stiffening perpendicular to direction of compression, *Vol 1, Pt 6, Ch 2, 3.8 Secondary stiffening perpendicular to direction of compression*

(c) Buckling of primary members, *Vol 1, Pt 6, Ch 2, 3.9 Buckling of primary members*

3.4 Shear strength – Simplified assessment method ESA1

3.4.1 If the simplified analysis method is adopted for extreme strength assessment, the shear strength of the ship at each critical section is to satisfy the following criterion:

$$\frac{\mid Q_{\mathrm{REX}} \mid A_{\mathrm{Z}}}{I\,\delta_{0}} \leq \tau_{\mathrm{p}}$$

where

δ_0 is to be taken as the minimum value of δ_i

τ_p = maximum permissible mean shear stress, in N/mm^2

= $f_{\tau EX}\,\tau_o$

$f_{\tau EX}$ = 0,9, limiting hull shear stress coefficient

Q_{REX} = extreme vertical wave and still water shear force, in kN, at the appropriate longitudinal position determined from *Vol 1, Pt 5, Ch 4, 4.7 Extreme hull girder design loads*

A_z, I and δ_i, are given in *Vol 1, Pt 6, Ch 4, 2.3 Shear strength 2.3.5*

f_{hts} and τ_o are defined in *Vol 1, Pt 6, Ch 4, 1.3 Symbols and definitions 1.3.1*

3.4.2 The design extreme shear stress due to extreme hull vertical shear forces for each structural member, τ_{ex}, due to hull girder is given by

$$\tau_{\mathrm{ex}} = \frac{\mid Q_{\mathrm{REX}} \mid A_{Z}}{I\,\delta_{\mathrm{i}}} \leq \tau_{\mathrm{p}}$$

where

Q_{REX} is given in *Vol 1, Pt 6, Ch 4, 3.4 Shear strength – Simplified assessment method ESA1 3.4.1*

A_z, I and δ_i are given in *Vol 1, Pt 6, Ch 4, 3.4 Shear strength – Simplified assessment method ESA1 3.4.1*

3.4.3 The following Sections on buckling control are to be complied with based on shear stresses derived in accordance with *Vol 1, Pt 6, Ch 4, 3.4 Shear strength – Simplified assessment method ESA1 3.4.2*:

(a) Plating subject to pure in-plane shear, *Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements*
(b) Shear buckling of stiffened panels, *Vol 1, Pt 6, Ch 2, 3.6 Shear buckling of stiffened panels*

The design factors of safety are given in *Vol 1, Pt 6, Ch 5 Structural Design Factors*.

3.5 Bending and shear strength – Ultimate strength analysis method ESA2

3.5.1 The extreme strength capability of the hull girder may be assessed using a direct calculation ultimate strength analysis method. In this case the longitudinal strength of the ship at each critical section is to satisfy the following criteria for hogging and sagging conditions:

(a) $M_{REX} < f_{UEX}\,M_{UEX}$
(b) Q_{REX} , $f_{UEX}\,Q_{UEX}$

where

M_{REX} = extreme vertical wave and still water bending moment, in kNm, given in *Vol 1, Pt 5, Ch 4, 4.7 Extreme hull girder design loads*

M_{UEX} = ultimate bending strength of the critical section, in kNm

Q_{REX} = extreme vertical wave and still water shear force, in kN, at the appropriate longitudinal position determined from *Vol 1, Pt 5, Ch 4, 4.7 Extreme hull girder design loads*

Q_{UEX} = ultimate shear strength of the critical section, in kN

f_{UEX} = 0,9, limiting ultimate strength coefficient for extreme hull girder strength assessment.

3.5.2 The ultimate strength of each critical section is to be derived by direct calculation using elasto-plastic analysis methods.

3.5.3 If the methods used to derive the ultimate strength do not include allowance for shear loading, then the shear strength requirements of *Vol 1, Pt 6, Ch 4, 3.4 Shear strength – Simplified assessment method ESA1* are to be applied.

■ *Section 4* Residual Strength Assessment, RSA

4.1 Application

4.1.1 This Section gives the requirements and procedures to be adopted for the application of the residual strength assessment procedure.

4.1.2 The following definition gives the basic default mission statement for the residual strength capability. The ship is required to have a 95 per cent probability of surviving for 96 hours, after sustaining structural damage as a consequence of military action, collision or grounding, in wave conditions that have a probability of occurring for 80 per cent of the time.

4.1.3 Three assessment levels are available for the residual strength assessment notation as detailed in *Vol 1, Pt 6, Ch 4, 1.2 Hull girder strength notations*

4.1.4 For the **RSA1** residual strength assessments the residual strength after damage is to be verified using the simplified assessment method given in *Vol 1, Pt 6, Ch 4, 4.4 Bending strength – Simplified assessment method RSA1* and *Vol 1, Pt 6, Ch 4, 4.5 Shear strength – Simplified assessment method RSA1*. This uses elastic theory, based on the remaining section moduli and area after damage, and determination of the buckling strength to resist the global hull girder loads.

4.1.5 For the **RSA2** residual strength assessments, the residual strength after damage is to be verified using the ultimate strength analysis method which determines the ultimate strength of the hull after damage using direct calculation methods. The assessment criteria are given in *Vol 1, Pt 6, Ch 4, 4.6 Bending and shear strength – Ultimate strength analysis method RSA2*

4.1.6 For the **RSA3** residual strength assessments, the residual strength after damage is to be verified using a recognised finite element code suitable for this type of analysis. The failure will be determined by the criteria implicit in the finite element code chosen. Several assessment codes are available and the calculation should be performed by a competent and experienced body with relevant experience.

4.1.7 All critical sections to be assessed are to be considered for all damage scenarios, irrespective of whether the critical section is damaged or not.

4.1.8 For damage scenarios that involve flooding of the ship, the effects of the flood water on the still water shear forces and bending moments are to be considered in the residual strength assessment at all critical locations whether they are damaged or not. In the latter case the capability of the undamaged critical section will be based on the structural capability of the intact section.

4.2 Extent of damage and analysis

4.2.1 The extent of damage to be considered is defined below. Unless otherwise specified by the Owner it will not be necessary to consider the consequences of combining damage extents from different weapon threats or damage scenarios.

4.2.2 The extent of damage due to military threats is defined as the minimum of the shock or blast damage that is likely to result from a specified weapon threat. The weapon threat may be specified by any of the following:

- the residual strength notation threat level, *see Vol 1, Pt 4, Ch 2, 7 Residual strength*
- the Owner;
- as a direct consequence of requirements of other notations.

4.2.3 Collision damage to the side shell. The standard damage extent is to be taken as:

Level A

- 5 m longitudinally between bulkheads
- from the waterline up to the main deck
- inboard for B/5 m.

Level B and C

- 5 m longitudinally anywhere including bulkheads

- from the bilge keel up to the main deck
- inboard for B/5 m.

4.2.4 Grounding or raking damage to the bottom structure. The standard grounding damage extent is to be taken as:

Level A

- length of 5 m anywhere forward of midships
- upwards for 1 m or to the underside of the inner bottom, whichever is less
- breadth of 2,5 m.

Level B and C

- length of 0,1L_R anywhere forward of midships
- upwards for 1 m or to the underside of the inner bottom, whichever is less
- breadth of 5 m

4.2.5 For the Levels A and B residual strength assessment, the residual strength is to be considered at a minimum of three critical sections for each anticipated damage extent. The critical sections are to be taken in the midship region and near each quarter length location. For the Level C residual strength assessment, the residual strength is to be considered at all critical sections along the length for each anticipated damage extent.

4.2.6 The damage requirements used for the residual strength assessment should be clearly identified in the Loading Manual or Stability Information Book.

4.3 Determination of critical sections

4.3.1 The effective geometric properties of critical transverse sections in way of the damaged area are to be calculated in accordance with *Vol 1, Pt 6, Ch 4, 2.1 General* and *Vol 1, Pt 6, Ch 4, 1.4 Calculation of hull section modulus*. In defining the longitudinal position of each critical section, the shadow areas associated with the damage and other openings specified in *Vol 1, Pt 6, Ch 4, 1.4 Calculation of hull section modulus 1.4.13* are to be considered together with the proximity of other openings, *see Vol 1, Pt 6, Ch 4, 1.4 Calculation of hull section modulus 1.4.15*. The effectiveness of the superstructure may also need to be re-evaluated.

4.3.2 Due attention is to made to the effectiveness of structure which may have been plastically deformed, as a consequence of the damage, on the ultimate strength after damage.

4.3.3 For Level 1 and 2 residual strength assessments, damaged areas are to be considered at approximately the longitudinal positions $L_R/4$, $L_R/2$ and $3L_R/4$. The geometric properties of critical transverse sections in way of these damaged areas are to be considered. Other longitudinal positions may also need to be considered depending on the internal arrangement or structural arrangement of the ship or the specified residual strength requirements.

4.3.4 For Level 3 residual strength assessment, damaged areas are to be considered at all positions along the length. Typically, it is expected that the local critical transverse section between adjacent main watertight bulkheads will be evaluated.

4.4 Bending strength – Simplified assessment method RSA1

4.4.1 If the simplified analysis method is adopted for residual strength assessment, the longitudinal strength of the ship at each critical section is to satisfy the following criteria for the hogging and sagging conditions:

$$\sigma_{BRS} < \sigma_p$$
$$\sigma_{DRS} < \sigma_p$$

where

σ_p = is the maximum permissible hull vertical bending stress, in N/mm^2

= $f_{\sigma RS}\, \sigma_o$

$f_{\sigma RS}$ = 0,9, limiting hull bending stress coefficient

σ_{DRS} is the hull girder bending stress at strength deck

$$= \frac{M_{\mathrm{RRS}}}{1000 Z_{\mathrm{DRS}}}$$

σ_{BRS} is the hull girder bending stress at keel

$$= \frac{M_{\mathrm{RRS}}}{1000 Z_{\mathrm{BRS}}}$$

M_{RRS} = residual strength design vertical bending moment, in kNm, given in *Vol 1, Pt 5, Ch 4, 5.7 Residual strength hull girder design loads*

Z_{DRS} = actual section modulus at deck of damaged section, in m^3, *see also Vol 1, Pt 6, Ch 4, 4.1 Application 4.1.8*

Z_{BRS} = actual section modulus at keel of damaged section, in m^3, *see also Vol 1, Pt 6, Ch 4, 4.1 Application 4.1.8*

f_{hts} and σ_o are defined in *Vol 1, Pt 6, Ch 4, 1.3 Symbols and definitions 1.3.1*.

4.4.2 The design residual strength stress due to the Residual strength design vertical bending moment, σ_{rs}, for each structural member is given by:

$$\sigma_{\mathrm{rs}} = \frac{M_{\mathrm{RRS}}}{1000 Z_{\mathrm{i}}}$$

where

Z_i = actual section modulus at structural element being considered, in m^3

M_{RRS} is defined in *Vol 1, Pt 6, Ch 4, 4.4 Bending strength – Simplified assessment method RSA1 4.4.1*

4.4.3 It is not necessary to satisfy the plate panel buckling requirements for compressive stresses provided that shear buckling of plate panels and all buckling modes of failure for longitudinal girders and stiffeners are satisfied. The design factors of safety are given in *Vol 1, Pt 6, Ch 5 Structural Design Factors*

4.4.4 Consequently, the following Sections on buckling control are to be complied with, based on compressive stresses derived in accordance with *Vol 1, Pt 6, Ch 4, 4.4 Bending strength – Simplified assessment method RSA1 4.4.2*

(a) Secondary stiffening in direction of compression, *Vol 1, Pt 6, Ch 2, 3.7 Secondary stiffening in direction of compression*
(b) Secondary stiffening perpendicular to direction of compression, *Vol 1, Pt 6, Ch 2, 3.8 Secondary stiffening perpendicular to direction of compression*
(c) Buckling of primary members, *Vol 1, Pt 6, Ch 2, 3.9 Buckling of primary members*

4.5 Shear strength – Simplified assessment method RSA1

4.5.1 If the simplified analysis method is adopted for residual strength assessment, the shear strength of the ship after damage at each damaged critical section is to satisfy the following criterion:

$$\frac{|\, Q_{\mathrm{RRS}} \,|\, A_{\mathrm{Z}}}{I\, \delta_{\mathrm{o}}} \leq \tau_{\mathrm{p}}$$

where

δ_0 is to be taken as the minimum value of δ_i,

and

τ_p = maximum permissible mean shear stress, in N/mm^2

= $f_{\tau EX} \tau_o$

$f_{\tau EX}$ = 0,9, limiting hull shear stress coefficient

Q_{RRS} = residual strength design shear force, in kN, at the appropriate longitudinal position determined from *Vol 1, Pt 5, Ch 4, 5.7 Residual strength hull girder design loads*

A_z, I and δ_i, are to be calculated in accordance with the method in *Vol 1, Pt 6, Ch 4, 2.3 Shear strength* for the damaged section, *see also Vol 1, Pt 6, Ch 4, 4.1 Application 4.1.8*.

f_{hts} and τ_o are defined in *Vol 1, Pt 6, Ch 4, 1.3 Symbols and definitions 1.3.1*.

4.5.2 The design extreme shear stress due to residual strength design shear force for each structural member, τ_{rs} , is given by

$$\tau_{\mathrm{rs}} = \frac{|\, Q_{\mathrm{RRS}} \,|\, A_{\mathrm{Z}}}{I\, \delta_{\mathrm{o}}}$$

where

Q_{RRS} is given in *Vol 1, Pt 6, Ch 4, 4.5 Shear strength – Simplified assessment method RSA1 4.5.1*

A_z, I and δ_i are given in *Vol 1, Pt 6, Ch 4, 2.3 Shear strength 2.3.5*

4.5.3 The following Sections on buckling control are to be complied with based on shear stresses derived in accordance with *Vol 1, Pt 6, Ch 4, 4.5 Shear strength – Simplified assessment method RSA1 4.5.2*:

(a) Plating subject to pure in-plane shear, *Vol 1, Pt 6, Ch 2, 4.3 Natural frequency of plate*.
(b) Shear buckling of stiffened panels, *Vol 1, Pt 6, Ch 2, 3.6 Shear buckling of stiffened panels*.

The design factors of safety are given in *Vol 1, Pt 6, Ch 5 Structural Design Factors*

4.6 Bending and shear strength – Ultimate strength analysis method RSA2

4.6.1 The residual strength capability of the damaged hull girder may be assessed using a direct calculation ultimate strength analysis method. In this case the longitudinal strength of the ship at each critical section is to satisfy the following criteria for the hogging and sagging conditions:

where

$M_{RRS} < f_{URS}\, M_{URS}$

$Q_{RRS} < f_{URS}\, Q_{URS}$

M_{RRS} = residual strength design vertical bending moment, in kNm, given in *Vol 1, Pt 5, Ch 4, 5.7 Residual strength hull girder design loads*

M_{URS} = ultimate bending strength of the damaged critical section, in kNm, *see also Vol 1, Pt 6, Ch 4, 4.1 Application 4.1.8*

Q_{RRS} = residual strength design shear force, in kN, at the appropriate longitudinal position determined from *Vol 1, Pt 5, Ch 4, 5.7 Residual strength hull girder design loads*

Q_{URS} = ultimate shear strength of the damaged critical section, in kN

f_{URS} = 0,9, limiting ultimate strength coefficient for residual strength assessment.

4.6.2 The ultimate strength of each critical section is to be derived by direct calculation using elasto-plastic analysis methods.

4.6.3 If the methods used to derive the ultimate strength do not include allowance for shear loading, then the shear strength requirements of *Vol 1, Pt 6, Ch 4, 4.5 Shear strength – Simplified assessment method RSA1* are to be applied.

■ *Section 1* Structural design factors

1.1 Application

1.1.1 The requirements of this Chapter are applicable to ships of steel construction.

1.2 General

1.2.1 This Chapter gives the allowable design criteria to be used to assess the structure.

1.2.2 These design criteria are to be used in the design formulae in *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements* as the design criteria for the scantling determination of NS2 and NS3 ships.

1.2.3 These criteria are also to be used when direct calculation methods are proposed as a supplement to the scantling determination procedures for all ships including NS1 ships.

1.2.4 Where higher tensile steel is used in the ship structure special consideration is to be given to the fatigue performance in accordance with *Vol 1, Pt 6, Ch 6, 2.5 Mechanical properties for design*

1.3 Higher tensile steel

1.3.1 Where higher tensile steels are used, the yield stress is to be adjusted by a factor f_{hts}, where f_{hts} is to be taken from *Table 5.1.1 High tensile steel stress correction factor f hts*

1.3.2 The f_{hts} factor is to be separately calculated for stresses that are a direct consequence of global loads and for stresses that are a direct consequence of local loads, as indicated in *Table 5.1.1 High tensile steel stress correction factor f hts*

Table 5.1.1 High tensile steel stress correction factor f_{hts}

Minimum yield stress σ_o N/mm^2	f_{hts} factor	
	Global loads	Local loads
235	1,000	1,00
265	0,964	1,00
315	0,956	1,00
355	0,919	1,00
>390	0,886 $\left(\dfrac{390}{\sigma_o}\right)$	0,91 $\left(\dfrac{390}{\sigma_o}\right)$

Note 1. Intermediate values may be obtained by linear interpolation.

Note 2. The higher tensile steel stress correction factor f_{hts} is applicable for NS1 ships as well as NS2 and NS3 ships.

Section 2
Scantling determination for NS1 ships

2.1 Design criteria

2.1.1 The local scantling requirements of higher tensile steel plating, longitudinals, stiffeners and girders may be based on a k_s factor determined as follows:

$$k_s = \frac{235}{\sigma_0}$$

or 0,66 whichever is greater

where

σ_o = specified minimum yield strength of material in N/mm^2

2.1.2 The global scantling requirements of higher tensile steel plating, stiffeners and primary members are based on a k_L factor defined as follows, *see Vol 1, Pt 6, Ch 5, 2.1 Design criteria 2.1.3*:

$$k_L = \frac{235}{f_{hts}\,\sigma_o}$$

where

f_{hts} is the higher tensile steel correction factor for global loads, *see Vol 1, Pt 6, Ch 5, 1.3 Higher tensile steel*

2.1.3 Where different grades of steel are used for the plating and attached stiffeners, then the higher tensile steel factor, k_L is to be based on the lower material yield strength.

Section 3
Scantling determination for NS2 and NS3 ships

3.1 Design criteria

3.1.1 The allowable stress coefficients for plating and stiffening required by *Vol 1, Pt 6, Ch 3, 2 Minimum structural requirements* for use in plating and stiffening design equations in *Vol 1, Pt 6, Ch 2, 2.7 Plating general* and *Vol 1, Pt 6, Ch 2, 2.8 Stiffening general* are to be determined as follows:

$f_\sigma = f_1 f_{hts}$

$f_\tau = f_1 f_{hts}$

$f_\delta = f_1$

where

f_1 is taken from *Table 5.3.2 Allowable stress factors f 1* as specified by *Table 5.3.1 Specification of design criteria value f $_1$*

f_{hts} is the correction factor for higher tensile steel given in *Vol 1, Pt 6, Ch 5, 1.3 Higher tensile steel*

3.1.2 The buckling factors of safety for plating and stiffeners are given in *Table 5.3.2 Allowable stress factors f 1* and are to be used in conjunction with the buckling requirements specified in *Vol 1, Pt 6, Ch 2, 3 Buckling*

3.1.3 The assessment of scantling requirements to satisfy the impact or slamming pressure loads for plating and stiffening are given in *Vol 1, Pt 6, Ch 3, 14 Strengthening for bottom slamming* and *Vol 1, Pt 6, Ch 3, 15 Strengthening for wave impact loads above waterline*

Table 5.3.1 Specification of design criteria value f_1

Failure mode	Stress factor	Column for f_1 in *Table 5.3.2 Allowable stress factors f 1*
Plating requirements		
Membrane stresses	f_σ	Use σ_x or σ_y column (1)
Local plate bending	f_σ	Use $\sigma_b$column
Shear stresses	f_τ	Use τ_{xy} column
Buckling, hull girder stresses	λ_σ	Use λ_σ column
Shear buckling, hull girder stresses	λ_τ	Use λ_τ column
Stiffener requirements		
Section modulus	f_σ	Use σ_x or σ_y column (1)
Web area	f_τ	Use τ_{xy} column
Inertia	f_δ	Use f_δ column
Buckling modes	λ_σ	Use λ_σ column
Note Use the σ_x or σ_y column as appropriate to the structure under consideration.		

Table 5.3.2 Allowable stress factors f_1

Structural item	Limiting stress and other criteria						
Longitudinally effective structure	Combined Stress	Longitudinal stress or stiffener bending stresses	Shear stress in Plating and Stiffener webs	Local plate bending	Deflection ratio for primary members and secondary stiffeners (3)	Buckling factor (5) Compressive stresses	Buckling factor (7) Shear stresses
Normal stress descriptor	σ_{vm}	σ_x	τ_{xy}	σ_b	f_δ	λ_σ	λ_τ
Longitudinal plating							
Bottom shell plating	0,90	0,75	-	f_2	0,00125 (1)	1,0	-
Inner bottom plating	0,90	0,75f_{WT}	-	$f_2 f_{WT}$	0,00125 (1)	1,0	-
Upper deck, outboard the line of openings	0,90	0,75	-	f_2	0,00100 (1)	1,0	-
Side shell plating	0,90	0,75	0,80	0,9f_2	0,00125 (1)	1,0	1,1
Longitudinal bulkhead plating	0,90	0,75	0,80	0,9f_2	0,00125 (1)	1,0	1,1
Inner skin plating	0,90	0,75	0,80	0,9f_2	0,00125 (1)	1,0	1,1
Intermediate decks	-	-	-	0,65	-	-	-
Longitudinal primary members							
Double bottom girders	0,90	0,75	0,80	-	0,00100 (2)	1,0	1,1
Longitudinal girders	-	0,75	0,65	-	0,00100 (2)	1,0	1,1
Longitudinal stringer plating and diaphragms	-	0,75	0,65	-	0,00100 (2)	1,0	1,1
Longitudinal secondary stiffeners	0,90	f_2	0,65	-	*see* above plating	1,1 (4)	-

Other longitudinal plating and secondary stiffeners							
Superstructures/deckhouses (partially longitudinally effective)	0,90	0,75	0,65	-	0,00167 (1)	1,0	-
Watertight bulkheads and internal boundaries plating	0,90	0,75	0,80	f_{WT}	-	1,0	1,1
primary members	-	0,90f_{WT}	0,90f_{WT}	-	0,00100 f_{WT} (2)	1,1	-
secondary stiffeners	-	0,90f_{WT}	0,95f_{WT}	-	0,00167 f_{WT}(1)	1,1 (4)	-
Deep tank bulkheads and internal boundaries plating	0,90	0,75	0,80	0,65f_{DT}	-	1,0	1,1
primary members	-	0,75f_{DT}	0,75f_{DT}	-	0,00080 f_{DT} (1)	1,1	-
secondary stiffeners	-	0,65f_{DT}	0,65f_{DT}	-	0,00100 f_{DT}(1)	1,1 (4)	-
Normal stress descriptor	σ_{vm}	σ_y	τ_{xy}	σ_b	f_δ	λ_σ	λ_τ
Transverse plating							
Watertight bulkheads and internal boundaries	1,00	1,00	0,80	1,00f_{WT}	0,00167 f_{WT} (1)	1,0	1,1
Deep tank bulkheads and boundaries	0,75	0,65	0,65	0,65f_{DT}	0,00100 f_{DT}(1)	1,2	1,2
Cross deck structure at ends of major openings	0,75	0,65	0,65	0,50	0,00100 (1)	1,1	1,1
Superstructures/deckhouses (local loads only)	-	0,75	-	0,75	0,00167 (1)	-	-
Transverse primary members							
Double bottom floors	0,75	0,65	0,65		0,00100 (2)	1,1	1,2
Web frames	-	0,65	0,65	-	0,00100 (2)	1,1	-
Side frames	-	0,65	0,65	-	0,00100 (2)	1,1	-
Transverse beams	-	0,65	0,65	-	0,00100 (2)	1,1	-
Watertight bulkheads and internal boundaries	-	0,90f_{WT}	0,90f_{WT}	-	0,00100 f_{WT}(2)	1,1	-
Deep tank bulkheads and internal boundaries	-	0,75f_{DT}	0,75f_{DT}	-	0,00080 f_{DT}(2)	1,1	-
Transverse secondary stiffeners							
Watertight bulkheads and internal boundaries	-	0,95f_{WT}	0,95f_{WT}	-	*see* above plating	1,1 (4)	-
Deep tank bulkheads and internal boundaries	-	0,65f_{DT}	0,65f_{DT}	-		1,1 (4)	-
Other secondary stiffeners	-	0,65	0,65	-		1,1 (4)	-
Structure for aircraft and vehicle operation (8) (Additional requirements in accordance with Pt 4, Ch 3,2)	Com-bined Stress	Primary member and stiffener bending stress	Shear stress in primary member and Stiffener webs	Local plate bending	Deflection ratio for primary members and secondary stiffeners (3)	Buckling factor of safety (6)	Buckling factor of safety (7)
Normal stress descriptor	σ_{vm}	σ_x or σ_y	τ_{xy}	σ_b	f_δ	λ_σ	λ_τ

Vehicles and aircraft parking areas	secondary stiffeners	-	0,75 (8)	0,75	-	0,00100 (1)	-	-
	primary members	-	0,60 (8)	0,60	-	0,00080 (2)	-	-
Aircraft normal landing areas	secondary stiffeners	-	0,75 (8)	0,75	-	0,00100 (1)	-	-
	primary members	0,70	0,65 (8)	0,65	-	0,00080 (2)	-	-
Aircraft emergency landing areas	secondary stiffeners	-	1,00 (8)	1,00	-	0,00160 (1)	-	-
	primary members	-	1,00 (8)	1,00	-	0,00100 (2)	-	-
Symbols								

f_2 is applicable to stiffeners and plating subjected to global hull girder bending stresses and local bending stresses and is to be taken as follows:

for NS2 ships

$f_2 = 0{,}9\left(1{,}83 - \frac{\sigma_{hg}}{\sigma_a}\right)$ but not greater than 0,95. Note for initial design assessment f_2 may be taken as 0,75.

for NS3 ships

$f_2 = 0{,}75$

where

σ_{hg} is the stress due to hull girder bending in the appropriate structural item, *see Vol 1, Pt 6, Ch 4, 2 Hull girder strength*

σ_a is the lower of

(1) allowable hull girder bending stress, σ_p, given in *Vol 1, Pt 6, Ch 4, 2.2 Bending strength 2.2.3*

(2) $\frac{\sigma_{cr}}{\lambda_\sigma}$

λ_σ is the buckling factor for this item

σ_{cr} is the critical buckling stress, *see Vol 1, Pt 6, Ch 2, 3 Buckling*.

Additional design factors for deep tank and watertight bulkheads and boundaries

$f_{DT} = 0{,}90$

$f_{WT} = 1{,}40$ Note watertight plating is assessed using plastic design methods

Note 1. Deflection ratio for secondary stiffeners, expressed as a ratio of the stiffener's span, i.e. $\delta \le f_\delta$ span where δ is the deflection.

Note 2. Deflection ratio for primary structure, expressed as a ratio of the primary member's span, i.e. $\delta \le f_\delta$ span.

Note 3. The deflection ratios are applicable to the primary members and secondary stiffeners attached to the specified plating areas. The ratios are not applicable to the plating.

Note 4. The buckling factor of safety for stiffeners attached to plating which is allowed to buckle in the elastic mode due to the applied loads is to be taken as 1,25 *see also Vol 1, Pt 6, Ch 2, 4.5 Effect of submergence*.

Note 5. Buckling factor of safety to be applied to the compressive stress due to global longitudinal stresses.

Note 6. Buckling factor of safety to be applied to the compressive stress due to local stresses, either vertical or transverse.

Note 7. Buckling factor of safety to be applied to the shear stress.

Note 8. For longitudinally effective primary structure and longitudinal stiffeners, the stress factor is to be reduced by:0% at 0,0L_R,30% at 0,3L_R,30% at 0,7L_R,
0% at 1,0L_R,
with intermediate values determined by interpolation.

■ *Section 1* General

1.1 Application

1.1.1 The requirements of this Chapter are applicable to mono-hull ships of steel construction as defined in *18, Ch 1, 1 Background*.

1.2 General

1.2.1 This Chapter contains the general Rule requirements for the construction of steel ships using electric arc welding processes. Where alternative methods of construction are proposed, details are to be submitted for consideration by Lloyd's Register (hereinafter referred to as 'LR').

1.2.2 Specific requirements containing detailed information on testing, inspection and construction details can be found in the relevant Chapters of the *Naval Survey Guidance for Steel Ships*, or an otherwise specified and agreed standard.

1.3 Symbols and definitions

1.3.1 The symbols and definitions used in this Chapter are defined in the appropriate Section.

1.4 Builder's facilities

1.4.1 The buildings used for production and storage are to be of suitable construction and equipped to provide the required environment, and are also to comply with any specified standard(s)

1.4.2 The Surveyor is to be allowed unrestricted access during working hours to such parts of the Builder's establishment as may be necessary to ensure that the requirements of the Rules are being complied with.

1.5 Works inspection

1.5.1 Prior to the commencement of construction, the facilities are to be inspected to the satisfaction of the attending Surveyor. This will include the minimum quality control arrangements outlined in *Vol 1, Pt 6, Ch 6, 1.6 Quality control*

1.5.2 The Surveyor is to be satisfied that the Builder has the organisation and capability to construct ships to the standards required by the Rules.

1.5.3 The Builder is to be advised of the result of the inspection and all deficiencies are to be rectified prior to the commencement of production.

1.5.4 Where structural components are to be assembled and welded by subcontractors, the Surveyors are to inspect the sub-contractor's works to ensure that compliance with the requirements of this Chapter can be achieved.

1.6 Quality control

1.6.1 For compliance with *Vol 1, Pt 6, Ch 6, 1.5 Works inspection 1.5.2*, LR's methods of survey and inspection for hull construction and machinery installation are to include procedures involving the shipyard management, organisation and quality systems.

1.6.2 The extent and complexity of the quality systems will vary considerably depending on the size and type of ships and production output. LR will consider certification of the Builder in accordance with the requirements of one of the following systems:

(a) Quality Assurance System in accordance with an International or National Standard (i.e. ISO 9000 and BS ENISO 9001) with assessment and certification carried out by a nationally accredited body.
(b) LR's Quality Assurance Scheme for the Hull Construction of Ships.
(c) LR's Quality Assurance Scheme for the Construction of Special Service Craft.
(d) LR's locally accepted Quality Control System – The Builder is implementing a documented Quality Control System which controls the following activities:
 (i) Receipt storage and issue of materials, equipment, etc.
 (ii) Fabrication environment.
 (iii) Weld procedures and welder performance.
 (iv) Production fabrication.
 (v) Inspection of production processes.
 (vi) Installation of machinery, Mobility and Ship Type systems.
 (vii) Fitting-out.
 (viii) Tests and trials.
 (ix) Drawings and document control.
 (x) Records.

1.6.3 The 'documented' quality control system will in general require the Builder to have written procedures that describe clearly and unambiguously which of the activities specified in 1.6.2(d) is carried out, when it is carried out and by whom. These procedures will form part of the system manual which is also to contain a statement of management policy, organisation chart and statements of responsibilities. The manual is to be controlled in respect to the formal issue and revision.

1.6.4 Further details of LR's requirements are available on request from the local LR office.

1.7 Building environment

1.7.1 The ship is to be suitably protected during the building period from adverse weather and climatic conditions.

1.8 Storage areas

1.8.1 All materials are to be stored safely and in accordance with the manufacturer's requirements. Storage arrangements are to be such as to prevent deterioration through contact with heat, sunlight, damp, cold and poor handling.

1.8.2 All storage spaces provided by the Builder for welding consumables are to be suitable for maintaining them in good condition and are to be in accordance with the manufacturer's recommendations.

1.8.3 All materials are to be fully identifiable in the storage areas, and identification is to be maintained during issue to production.

1.8.4 Material suspected of being non-conforming is to be segregated from acceptable materials.

1.9 Materials handling

1.9.1 The Builder is to maintain purchasing documents containing a clear description of the materials ordered for use in hull construction and the standards to which the material must conform, together with the identification and certification requirements.

1.9.2 The Builder is to be responsible for ensuring that all incoming plates, sections, castings, components, fabrications and consumables and other materials used in the hull construction are inspected or otherwise verified as conforming to purchase order requirements.

1.9.3 The Builder is to have procedures for the inspection, storage and maintenance of Owner supplied materials and equipment.

1.9.4 The Builder is to record, on receipt, the manufacturing date, or use-by date of critical materials. Any materials which have a shelf life are to be used in order of manufacturing date to ensure stock rotation.

1.9.5 The Builder is to establish and maintain a procedure to ensure that materials and consumables used in the hull construction process are identified (by colour-coding and/or marking as appropriate) from arrival in the yard through to fabrication in such a way as to enable the type and grade to be readily recognised.

1.9.6 Where materials are found to be defective they are to be rejected in accordance with the Builder's quality control procedure.

1.10 Faults

1.10.1 All identified faults are to be recorded under the requirements of the quality control systems. Faults are to be classified according to their severity and are to be monitored during Survey.

1.10.2 Production faults are to be discussed with the Owner and attending Surveyor, and a rectification scheme agreed. Deviations from the approved plans are to be locally approved by the attending Surveyor and a copy forwarded to the plan approval office for record purpose.

1.11 New building inspection

1.11.1 On acceptance of a 'Request for Services' the attending Surveyor is to inform the Builder of the key stages of the production that are to be inspected and the extent of the inspection to be carried out.

1.11.2 It is the Builder's responsibility to carry out required inspections in accordance with the accepted quality control system.

1.11.3 It is the Surveyor's responsibility to monitor the Builder's quality control records and carry out inspections at key stages and during periodic visits.

1.11.4 Adequate facilities are to be provided to enable the Surveyor to carry out a satisfactory inspection. Consideration also needs to be given to provide arrangements that facilitate subsequent in-service maintenance. These are to include the provision of access holes in restricted spaces and removable linings.

1.11.5 During inspections all deviations are to be dealt with in accordance with *Vol 1, Pt 6, Ch 6, 1.6 Quality control 1.6.3*

1.11.6 Building and repair tolerances are given in the Naval Ship Survey Guidance Manual.

1.12 Acceptance criteria

1.12.1 Classification is dependent upon the work being carried out in accordance with the approved plans and the requirements of an accepted quality control system.

1.12.2 The work is to be carried out to the satisfaction of the attending Surveyor. This will include the verification of the quality control documentation and the remedial action associated with all defects and deficiencies recorded.

1.12.3 Proposed deviations from the approved plans are subject to LR approval and in the first instance are to be discussed with the attending Surveyor. Where applicable, an amended plan is to be submitted to the plan appraisal office. Such deviations will be recorded as endorsements to the classification unless specifically agreed otherwise with the plan appraisal office.

1.12.4 Where the above requirements are met the attending Surveyor will arrange for the relevant certification to be issued.

1.13 Repair

1.13.1 Minor repairs are to be agreed with the attending Surveyor and a rectification scheme agreed with the Builder. The Builder is to incorporate details of the agreed repair procedures in the quality control system in accordance with *Vol 1, Pt 6, Ch 6, 1.6 Quality control 1.6.3*

1.13.2 Repairs which affect the structural integrity are to be discussed with the Builder and the Builder's proposed rectification scheme is to be submitted to the plan appraisal office for consideration.

Section 2
Materials

2.1 General

2.1.1 The Rules relate in general to the construction of steel ships, although consideration will be given to the use of other materials.

2.1.2 Materials used in the construction of the ship are to be manufactured and tested in accordance with the requirements of the*Rules for the Manufacture, Testing and Certification of Materials, July 2015* (hereinafter referred to as the Rules for Materials.

2.1.3 Materials for which provision is not made therein or covered by this Section may be accepted, provided that they comply with an approved specification and such tests as may be considered necessary.

2.2 Grade of steel

2.2.1 The grade of steel, supply condition and its mechanical properties are to be indicated on the construction plans.

2.2.2 In order to distinguish between the material grade requirements for different hull members at varying locations along the ship, material classes are assigned, as shown in *Table 6.2.1 Material classes and grades*. For each class, depending on thickness, the material grade requirements are not to be lower than those given in *Table 6.2.2 Steel grades for normal operation*.

Table 6.2.1 Material classes and grades

Structural member category		Material class/Minimum grade
SECONDARY		
A1.	Longitudinal bulkhead strakes, other than belonging to the Primary category	Class I within 0,4L_R amidships
A2.	Deck plating exposed to weather, other than that belonging to the Primary or Special category	Grade A/AH outside 0,4L_R amidships
A3.	Side plating	
PRIMARY		
B1.	Bottom plating, including keel plate	
B2.	Strength deck plating, excluding that belonging to the Special category	Class II within 0,4L_R amidships
B3.	Continuous longitudinal plating of strength members above strength deck	Grade A/AH outside 0,4L_R amidships
B4.	Uppermost strake in longitudinal bulkhead	
SPECIAL		
C1.	Sheerstrake (or rounded gunwale) and stringer plate at strength deck, *see* Note 1	Class III within 0,4L_R amidships
C2.	Deck strake at longitudinal bulkhead, *see* Note 1	Class II outside 0,4L_R amidships
		Class I outside 0,6L_R amidships
C3.	Strength deck plating at corners of large hatch openings	Class III within 0,6L_R amidships
		Class II outside 0,6L_R amidships
C4.	Bilge strake in ships with double bottom over the full breadth and length less than 150 m	Class II within 0,6L_R amidships
		Class I outside 0,6L_R amidships
C5.	Bilge strake in other ships, *see* Note 1	Class III within 0,6L_R amidships

		Class II outside 0,4L_R amidships Class I outside 0,6L_R amidships
ADDITIONAL REQUIREMENTS FOR SINGLE STRENGTH DECK SHIPS OF LENGTH GREATER THAN 150 m		
D1.	Longitudinal plating of strength deck where contributing to the longitudinal strength	Grade B/AH within 0,4L_R amidships
D2.	Continuous longitudinal strength plating of members above strength deck	
D3.	Single side strakes for ships without inner continuous longitudinal bulkhead(s) between bottom and strength deck	
ADDITIONAL REQUIREMENTS FOR SHIPS OF LENGTH GREATER THAN 250 m		
E1.	Sheerstrake (or rounded gunwale) and stringer plate at strength deck, *see* Note 1	Grade E/EH within 0,4L_R amidships
E2.	Bilge strake, *see* Note 1	Grade D/DH within 0,6L_R amidships

Note 1. Single strakes required to be of Class III or of Grade E/EH and within 0,4L_R amidships are to have breadths not less than 800 + 5L_R mm, but need not be greater than 1800 mm, unless limited by the geometry of the ship's design.

Note 2. For strength members not mentioned, Grade A/AH may be generally used.

Note 3. Steel grade is to correspond to the as-fitted thickness.

Note 4. Plating materials for sternframes supporting the rudder and propeller boss, rudders, rudder horns and shaft brackets are, in general, not to be of lower grades than corresponding to Class II. For rudder and rudder body plates subjected to stress concentrations (e.g. in way of lower support of semispade rudders or at upper part of spade rudders) Class III is to be applied.

Note 5. RAS seating and support structure are to be of Grade D/DH for $t \leq 20$ mm and Grade E/EH for $t > 20$ mm. For ships operating in cold weather RAS seating and support structure are to be of Grade E/EH.

Note 6. Corner inserts in way of complex openings such as for lifts and side doors which may impinge on the deck plating or stringer plate are to be of Grade D/DH for $t \leq 20$ mm and Grade E/EH for $t > 20$ mm.

Note 7. The material class used for reinforcement and the quality of material (i.e. whether mild or higher tensile steel) used for welded attachments, such as waterway bars and bilge keels, is to be similar to that of the hull envelope plating in way. Where attachments are made to rounded gunwale plates, special consideration will be given to the required grade of steel, taking account of the intended structural arrangements and attachment details.

Note 8. The material class for deck plating, sheerstrake and upper strake of longitudinal bulkhead within 0,4L_R amidships is also to be applied at structural breaks of the superstructure, irrespective of position.

Note 9. Engine seat top plates outside 0,6L_R amidships may be Grade A/AH. Steel grade requirement for top plates within 0,6L_R amidships will be specially considered.

Table 6.2.2 Steel grades for normal operation

Thickness, in mm	Material Class					
	I		II		III	
	Mild steel	H.T. steel	Mild steel	H.T. steel	Mild steel	H.T. steel
≤10	A	AH	A	AH	A	AH
10-15	A	AH	A	AH	A	AH
15-20	A	AH	A	AH	B	AH
20-25	A	AH	B	AH	D	DH
25-30	A	AH	D	DH	D	DH
30-35	B	AH	D	DH	E	EH

35-40	B	AH	D	DH	E	EH
40-45	D	DH	E	EH	E	EH
45-50	D	DH	E	EH	E	EH

2.2.3 Ships operating in certain environmental conditions, and those where operational requirements may lead to a risk of impact damage, or ships with military notations, may require higher toughness grades.

2.2.4 Where a ship has the notations **FDA**, **ESA** or **RSA**, the toughness requirements for steel will be specially considered on the basis of fatigue crack limitation and subsequent propagation through the structure.

2.2.5 When plate material, intended for welded construction, will be subject to significant strains in a direction perpendicular to the rolled surfaces, it is recommended that consideration be given to the use of special plate material with specified through thickness properties, and tested in accordance with *Ch 3, 8 Plates with specified through thickness properties* of the Rules for Materials. The plan should indicate the material grade followed by the letter Z (e.g. DZ, DHZ).

2.3 Refrigerated spaces

2.3.1 Where the minimum design temperature of the steel falls below 0°C in refrigerated spaces, the grade of steel for the following items is to comply, in general, with the requirements of *Table 6.2.3 Grades of steel for refrigerated spaces with a minimum design temperature below 0 Degrees C*:

- Deck plating.
- Webs of deck girders.
- Longitudinal bulkhead strakes attached to deck.

Table 6.2.3 Grades of steel for refrigerated spaces with a minimum design temperature below 0 Degrees C

Minimum design temperature, in °C	Thickness, in mm	Grades of steel
0 to -10	$t \leq 12,5$	B/AH
	$12,5 < t \leq 25,5$	D/DH
	$t > 25,5$	E/EH
< –10 to –25	$t \leq 12,5$	D/DH
	$t > 12,5$	E/EH
< –25 to –40	$t \leq 12,5$	E/EH
	$t > 12,5$	FH/LT-FH (*see also Ch 3, 6 Ferritic steels for low temperature service*)

2.3.2 Unless a temperature gradient calculation is carried out to assess the design temperature in the items defined in *Vol 1, Pt 6, Ch 6, 2.3 Refrigerated spaces 2.3.1*, the temperature to which the steel deck may be subjected is to be assessed as shown in *Table 6.2.4 Assessment of deck temperature*

Table 6.2.4 Assessment of deck temperature

Arrangement	Deck temperature
(1) Deck not covered with insulation in the refrigerated space	Temperature of the refrigerated space
(2) Deck covered with insulation in the refrigerated space and not insulated on the other side	Temperature of the space on the uninsulated side

(3) Deck covered with insulation on both sides	
(a) Temperature difference not greater than 11°C	Mean of the temperatures of the spaces above and below the deck
(b) Temperature difference greater than 11°C but not greater than 33°C	Mean of the temperatures of the spaces above and below the deck less 3°C
(c) Temperature difference greater than 33°C	Deck temperature will be specially assessed
Note Where one of the internal spaces concerned is not refrigerated, the temperature of the space is to be taken as 5°C.	

2.4 Ships operating in cold weather conditions

2.4.1 The material class and minimum grade requirements specified in *Table 6.2.1 Material classes and grades* and *Table 6.2.2 Steel grades for normal operation* are applicable for normal service, which assumes the navigation to areas where the lowest mean daily average air temperature is not less than –10°C.

2.4.2 Unless otherwise specified, all ships designed for sea area **SA1** and other ships intended to operate for extended periods in cold weather conditions, the material class and minimum grade requirements dependent on thickness are to be in accordance with*Table 6.2.5 Material classes and grades for structures exposed to low temperatures* and *Table 6.2.6 Steel grades for cold weather*. The requirements are based on a lowest mean daily average design air temperature of –30°C. Where an alternative design air temperature is required, the choice of material grades will be specially considered, *see also The Provisional Rules for the Winterisation of Ships*.

Table 6.2.5 Material classes and grades for structures exposed to low temperatures

Structural member category		Material class
SECONDARY		
A1.	Deck plating exposed to weather, other than that belonging to the Primary or Special category	Class I
A2.	Side plating above the Cold Waterline (CWL), *see* Note 4	
A3.	Transverse bulkheads above CWL, *see* Note 4	
PRIMARY		
B1.	Strength deck plating, excluding that belonging to the Special category, *see* Note 1	Class II within 0,4L_R amidships
B2.	Continuous longitudinal members above strength deck	Class I outside 0,4L_R amidships
B3.	Longitudinal bulkhead above CWL, *see* Note 4	
SPECIAL		
C1.	Sheerstrake (or rounded gunwale) and stringer plate at strength deck, *see* Note 2	Class III within 0,4L_R amidships
C2.	Deck strake at longitudinal bulkhead, *see* Note 3	Class II outside 0,4L_R amidships

Note 1 Plating at the corners of deck openings, superstructure ends and other structural discontinuity is to be specially considered. The requirements of Class III are to be applied in positions where high local stresses may occur but the material is not to be less than Grade E/EH.

Note 2 Not to be less than Grade E/EH within 0,4LR amidships in ships with length exceeding 250 m.

Note 3 In ships with breadth exceeding 70 m at least three deck strakes are to be Class III.

Note 4 The Cold Waterline (CWL) is to be taken as 0,3 m below the minimum design Ballast Waterline (BWL).

Table 6.2.6 Steel grades for cold weather

Thickness, in mm	Material Class					
	I		II		III	
	Mild steel	H.T. steel	Mild steel	H.T. steel	Mild steel	H.T. steel
≤10	B	AH	D	DH	D	DH
10-15	D	DH	D	DH	E	EH
15-20	D	DH	D	DH	E	EH
20-25	D	DH	E	EH	E	EH
25-30	D	DH	E	EH	E	EH
30-35	D	DH	E	EH	–	FH
35-40	E	EH	E	EH	–	FH
40-45	E	EH	–	FH	–	FH
45-50	E	EH	–	FH	–	FH

2.4.3 All bulwarks, spurn-waters, unlagged gas turbine intake structures, side screens, tie down points, etc. are to be constructed of steel of equivalent toughness to that of the material to which they are attached.

2.4.4 Steel grades for rudder horn and stem (including the adjacent strake of shell plating), are given in *Table 6.2.7 Steel grades for rudder horn, shaft brackets and stem for ships intended to navigate in Arctic or Antarctic conditions* The steel grades of internal members attached to these items are to be of the same grade (or equivalent) with due account taken of difference in thickness.

2.4.5 For non-exposed structures and structures below the Cold Waterline, the material grades are not to be lower than those given in *Table 6.2.1 Material classes and grades*.

2.4.6 Structure attached to and within a distance of 2,0 m within unheated spaces and 0,75 m for heated spaces of the exposed boundary plating is to be of the same material grade as that of the exposed plating, but the grade may be adjusted depending on the material thickness of the attached structure.

Table 6.2.7 Steel grades for rudder horn, shaft brackets and stem for ships intended to navigate in Arctic or Antarctic conditions

Item	Condition	Construction	Steel grade(2)(3)	
			f < 25(1)	$f \geq$ 25(1)
Rudder horn	Fully immersed	Cast steel	Carbon manganese steel Grade 400	Carbon manganese steel Grade 400
		Fabricated	Grade EH	Grade EH
	Periodically immersed or exposed	Cast steel	Carbon manganese steel Grade 460	2 1/4 Ni steel or equivalent
		Fabricated	Grade FH	1 1/2 Ni steel or equivalent
Shaft brackets	Fully immersed	Cast steel	Special Grade	Special Grade
		Fabricated	Class B/AH	Class B/AH
	Periodically immersed or exposed	Cast steel	Carbon manganese steel Grade 400	Carbon manganese steel Grade 460
		Fabricated	Class II	Grade FH
Stem including adjacent strake of shell plating	Fully immersed	Fabricated	Class B/AH	Class B/AH
		Cast steel	Carbon manganese steel Grade 400	Carbon manganese steel Grade 400
	Periodically immersed or exposed	Fabricated	Class II	Class II
		Cast steel	2 1/4 Ni steel	2 1/4 Ni steel
Rudder stock		Forged	*see Ch 5, 2.4 Mechanical tests 2.4.7* of the Rules for Materials	
		Cast steel	Carbon manganese steel grade 400	

Note 1. $f = \sqrt{P_0 \, \Delta} \times 10^{-3}$

Note where P_0 is the maximum propulsion shaft power, in kW, for which the machinery is classed Δ is displacement, in tonnes, at Ice Load Waterline or Deepest Ice Operation Waterline when floating in water of relative density of 1,0.

Note 2. For cast steel, *see Ch 4, 7 Ferritic steel castings for low temperature service* of Rules for Materials. The requirements for carbon manganese steel grades 400 and 460 are to include the additional compositional requirements for Special grade in accordance with*Ch 4, 2.2 Chemical composition* of the Rules for Materials.

Note 3. For C–Mn LT60 and Ni plates, *see Ch 3, 6 Ferritic steels for low temperature service* of Rules for Materials.

Note 4. For Special grade, *see Ch 4, 2.2 Chemical composition* of the Rules for Materials.

2.5 Mechanical properties for design

2.5.1 The scantlings determined within this Part of the Rules assume that mild steel has the following mechanical properties:

	N/mm^2
Yield strength (minimum)	235

Tensile strength	400–490
Modulus of elasticity	200 x 10^3

2.5.2 Steels having a minimum yield stress not less than 265 N/mm^2 are regarded as higher tensile steels.

2.5.3 Factors for structural assessment are given in *Vol 1, Pt 6, Ch 5 Structural Design Factors*

2.5.4 For the application of the requirements of *Vol 1, Pt 6, Ch 6, 2.5 Mechanical properties for design 2.5.3* special consideration will be given to steel where $\sigma_o \geq 390$ N/mm^2. Where such steel grades are used in areas which are subject to fatigue loading the structural details are to be verified using fatigue design assessment methods.

2.6 Paints and coatings

2.6.1 All steelwork is to be suitably protected against corrosion by a suitable protective coating. All coatings are to be in accordance with the requirements of this Section.

2.6.2 At the Owner's request, the **ShipRight ACS (B)** notation may be assigned to a vessel to indicate that paints and protective coatings have been applied to water ballast tanks in accordance with the *ShipRight Anti-Corrosion System Notations for Naval Ships* procedure during construction, *see Vol 1, Pt 1, Ch 2, 3.10 Other notations*.

2.6.3 The underwater portion of the hull is to be provided by means of a suitable high resistant paint applied in accordance with the manufacturer's requirements. Details of the high resistant paint are to be submitted for information (*see also Vol 1, Pt 1, Ch 3, 4.3 In-water Surveys*).

2.6.4 At the time of new construction, all salt-water ballast spaces having boundaries formed by the hull envelope shall have an efficient protective coating, epoxy or equivalent, applied in accordance with the manufacturer's recommendations.

2.6.5 Details and recommendations regarding the coating of salt-water ballast spaces are given in LR's *List of Paints, Resins, Reinforcements and Associated Materials* and the *ShipRight Anti-Corrosion System Notation for Naval Ships procedure*.

2.6.6 Integral tanks that contain only fuel, may be coated or, where applicable, be protected by a system of cathodic protection or both, *see Vol 1, Pt 6, Ch 6, 2.7 Cathodic protection*

2.6.7 Steelwork is to be suitably cleaned and cleared of millscale before the application of any coating.

2.6.8 Where a primer is used to coat steel after surface preparation and prior to fabrication, the composition of the coating is to be such that it will have no significant deleterious effect on subsequent welding work and that it is compatible with the paints or other coatings subsequently applied in association with an approved system of corrosion control.

2.6.9 To determine the influence of the primer coating on the characteristics of welds, tests are to be made as detailed in LR's *List of Paints, Resins, Reinforcements and Associated Materials*.

2.6.10 Paints or other coatings are to be suitable for the intended purpose in the locations where they are to be used. Coatings are to be of adequate film thickness, applied in accordance with the paint manufacturer's specification.

2.6.11 The paint or coating applied is to be compatible with any previously applied primer.

2.6.12 Paint containing aluminium should not, in general, be used in positions where oil or fuel vapours may accumulate, unless it has been shown by appropriate tests that the paint to be used does not increase the incendive sparking hazard.

2.6.13 Paints, varnishes and similar preparations having a nitro-cellulous or other highly flammable base are not to be used in accommodation or machinery spaces.

2.7 Cathodic protection

2.7.1 This section contains the requirements for the cathodic protection, where fitted, of the external hull and internal spaces.

2.7.2 Where an impressed current cathodic protection system is fitted, plans showing the proposed layout of anodes and hull penetrations are to be submitted.

2.7.3 The arrangement for glands, where cables pass through the shell, are to include a small cofferdam. Cables to anodes are not to be led through tanks intended for the carriage of low flash point oils. Where cables are led through cofferdams, they are to be enclosed in a substantial steel tube of about 10 mm thickness.

2.7.4 Where anodes are fitted on the hull, a plan showing their location and method of attachment is to be submitted in accordance with *Vol 1, Pt 6, Ch 1, 2.2 Plans to be submitted* They are to be fitted in such a way that they do not cause a stress concentration.

2.7.5 When a cathodic protection system is to be fitted in tanks for the carriage of liquid with flash point not exceeding 60°C, a plan showing details of the locations and attachment of anodes is to be submitted. The arrangements will be considered for safety against fire and explosion aspects only. Impressed current cathodic protection systems are not permitted in any tank.

2.7.6 Particular attention is to be given to the locations of anodes in relation to the structural arrangements and openings of the tank.

2.7.7 Anodes are to be of approved design and sufficiently rigid to avoid resonance in the anode support. Steel cores are to be fitted, and these are to be so designed as to retain the anode even when the latter is wasted.

2.7.8 Anodes are to be attached to the structure in such a way that they remain secure both initially and during service. The following methods of attachment would be acceptable:

(a) Steel core connected to the structure by continuous welding of adequate section.
(b) Steel core bolted to separate supports, provided that a minimum of two bolts with lock nuts are used at each support. The separate supports are to be connected to the structure by continuous welding of adequate section.
(c) Approved means of mechanical clamping.

2.7.9 Anodes are to be attached to stiffeners, or may be aligned in way of stiffeners on plane bulkhead plating, but they are not to be attached to the shell. The two ends are not to be attached to separate members which are capable of relative movement.

2.7.10 When locating anodes, care is to be taken to ensure that they do not cause a stress concentration. Where cores or supports are welded to the main structure, they are to be kept clear of the toes of brackets and similar stress raisers. Where they are welded to asymmetrical stiffeners, they are to be connected to the web with the welding kept at least 25 mm away from the edge of the web. In the case of stiffeners or girders with symmetrical face plates, the connection may be made to the web or to the centreline of the face plate but well clear of the free edges. However, it is recommended that anodes are not fitted to face plates of higher tensile steel longitudinals.

2.7.11 Aluminium and aluminium alloy anodes are permitted in tanks used for the carriage of oil, but only at locations where the potential energy does not exceed 275 J. The weight of the anode is to be taken as the weight at the time of fitting, including any inserts and fitting devices.

2.7.12 The height of the anode is, in general, to be measured from the bottom of the tank to the centre of the anode. Where the anode is located on, or closely above, a horizontal surface (such as a bulkhead girder) not less than 1,0 m wide, provided with an upstanding flange or face plate projecting not less than 75 mm above the horizontal surface, the height of the anode may be measured above that surface.

2.7.13 Aluminium anodes are not to be located under tank hatches unless protected by adjacent structure.

2.7.14 Magnesium or magnesium alloy anodes are permitted only in tanks intended solely for water ballast.

2.8 Bimetallic connections

2.8.1 The design shall ensure that the location of all bimetallic connections allows for regular inspection and maintenance of the joints and penetrations during service.

2.8.2 Where bimetallic connections are made, involving dissimilar metals, measures are to be incorporated to preclude galvanic corrosion.

2.8.3 Special attention is to be given to the penetrations of and connections to the hull, bulkheads and decks by piping and equipment where dissimilar materials are involved.

2.9 Deck coverings

2.9.1 The steel deck is to be coated with a suitable material in order to prevent corrosive action.

2.9.2 Deck coverings within accommodation spaces, control stations, stairways and passageways are to be of a type which will not readily ignite or cause a smoke hazard.

2.9.3 Where plated decks are sheathed with wood, or an approved construction of suitable thickness, reductions in plate thickness may be allowed.

2.10 Corrosion margin

2.10.1 The scantlings determined from the formulae provided in the Rules assume that the materials used are selected, manufactured and protected in such a way that there is negligible loss in strength due to corrosion.

2.10.2 Where steel is not protected against corrosion, by painting or other approved means, the scantlings may require to be further considered.

2.10.3 For naval auxiliaries with scantlings in accordance with the *Rules and Regulations for the Classification of Ships* **(NSA)** the corrosion margins, where specified in those Rules, are to be applied.

2.10.4 It is the responsibility of the Owner to specify corrosion margins which meet their operational requirements. Where the Owner does not specify corrosion margins, it is recommended that corrosion margins be applied to net scantlings calculated by these Rules in areas of the ship's structure where corrosion or wear may be expected to occur in service. The following recommendations are offered as guidance:

+0,5 mm all hull envelope plating below a line, 1,0 m, above the design waterline

+ 0,5 mm of all plating forming the boundary of tanks

+ 0,5 mm plating forming the lower boundary of wet spaces as appropriate

+2,0 mm to the keel plate

+ 1,5 mm to flight deck plating.

Consideration should also be given to the addition of a corrosion margin in the following areas:

- The lower portion of stiffeners located within wet spaces.
- Stiffeners located within tanks.
- All tanks containing corrosive fluids and areas where spillage of corrosive fluids could occur.
- The base of mast structures.
- All uncoated structures.

2.10.5 Where a corrosion margin is specified, submitted plans are to be in accordance with *Vol 1, Pt 6, Ch 1, 2.2 Plans to be submitted 2.2.1*.

2.10.6 Ships with an Owner specified corrosion margin will be eligible for an enhanced scantling notation, *see Vol 1, Pt 3, Ch 6, 6 Enhanced Scantlings*

■ *Section 3*
Requirements for welded construction

3.1 General

3.1.1 The requirements of this Section are applicable to grades of steel welded using electric arc welding processes. Where it is proposed to use alternative welding processes, details are to be submitted for approval, prior to the start of fabrication.

3.1.2 Symbols are defined as necessary in each Section.

3.1.3 Ships with enhanced shock notation are to additionally comply with the requirements of *Vol 1, Pt 4, Ch 2 Military Load Specification*

3.2 Information to be submitted

3.2.1 The plans and information submitted for approval are clearly to indicate details of the welded connections of the main structural members, including the type, disposition and size of welds. This requirement includes welded connections to steel castings.

3.2.2 The information to be submitted should include the following:

(a) Whether weld sizes given are throat thicknesses or leg lengths.

(b) Grades and thicknesses of materials to be welded.
(c) Location, types of joints and angles of abutting members.
(d) Reference to welding procedures to be used.
(e) Sequence of welding of assemblies and joining up of assemblies.

3.3 Welding equipment

3.3.1 Welding plant and equipment are to be in accordance with the requirements specified in *Ch 13, 1.8 Welding equipment and welding consumables* of the Rules for Materials.

3.4 Welding consumables

3.4.1 The requirements for welding consumables are to be in accordance with the requirements specified in *Ch 13, 1.8 Welding equipment and welding consumables* of the Rules for Materials.

3.4.2 The approval of welding consumables is to be in accordance with *Ch 11 Approval of Welding Consumables* of the Rules for Materials.

3.5 Welding procedures

3.5.1 Welding procedures are to be established for the welding of all joints in accordance with the requirements specified in *Ch 13, 1.9 Welding procedure and welder qualifications* of the Rules for Materials.

3.5.2 All welding procedures are to be tested and qualified in accordance with the requirements of *Ch 12 Welding Qualifications* of the Rules for Materials and are to be approved by the Surveyor prior to construction.

3.5.3 Welders and welding operators are to be proficient in the type of work to be undertaken and are to be qualified in accordance with the requirements specified in *Ch 12 Welding Qualifications* of the Rules for Materials.

3.6 Inspection

3.6.1 Effective arrangements are to be provided by the Shipbuilder for the inspection of all finished welds in order to ensure that all welding has been satisfactorily completed.

3.6.2 All finished welds are to be subjected to non-destructive examination in accordance with the requirements specified in *Ch 13, 2.12 Non-destructive examination of welds* of the Rules for Materials. Details of weld defect levels are given in the Naval Survey Guidance for Steel Ships.

3.6.3 Typical locations for volumetric examination and number of checkpoints to be taken are as shown in *Table 6.3.1 Recommended extent of NDE checkpoints*. A list of the proposed items to be examined is to be submitted for approval.

Table 6.3.1 Recommended extent of NDE checkpoints

Volumetric non-destructive examinations – recommended extent of testing, *see Ch 13, 2.12 Non-destructive examination of welds 2.12.12*		
Item	Location	Checkpoints (see Note 1)
Intersections of butts and seams of fabrication and section welds	Throughout:	
	(a) The hull envelope plating:	
	• at critical locations identified by FDA, *see* Note 2	All
	• at other highly stressed areas, *see* Note 3	All
	• remainder	1 in 2
	(b) longitudinal and transverse bulkheads	1 in 2
	(c) inner bottom	1 in 2
Butt welds in plating	Throughout	1 m in 25 m (*see* Notes 4 and 5)
Seam welds in plating	Throughout	1 m in 100 m

Butts in longitudinals	Hull envelope within 0,4L amidships Hull envelope outside 0,4L amidships	1 in 10 welds 1 in 20 welds
Bilge keel butts	Throughout	1 in 10 welds
Structural items when made with full penetration welding as follows: sheerstrake to deck stringer plate or angle	Throughout	1 m in 20 m
Note 1. The length of each checkpoint is to be between 0,3 m and 0,5 m. **Note** 2. FDA signifies the fatigue design assessment procedure. **Note** 3. Typically those at shear strake, deck stringer, keel strake and turn of bilge. **Note** 4. Checkpoints in butt welds and seam welds are in addition to those at intersections. **Note** 5. Welds at inserts used to close openings in hull envelope plating are to be checked by non-destructive examination. **Note** 6. Agreed locations are not to be indicated on the blocks prior to the welding taking place, nor is any special treatment to be given at these locations. **Note** 7. Particular attention is to be given to repair rates in longitudinal butts. Additional welds are to be tested in the event that defects such as lack of fusion or incomplete penetration are repeatedly observed.		

■ *Section 4* Welded joints and connections

4.1 General

4.1.1 Requirements are given in this Chapter for welding connection details, aluminium/steel transition joints, steel/wood connection, rivetting of light structure and adhesive bonding.

4.1.2 Welded joints are to be detailed such that crevices or inaccessible pockets capable of retaining dirt or moisture are avoided. Where cavities are unavoidable, they are to be sealed by welding or protective compounds or made accessible for inspection and maintenance.

4.2 Weld symbols

4.2.1 Weld symbols, where used, are to conform to a recognised National or International Standard. Details of such Standards are to be indicated on the welding schedule, which is to be submitted for appraisal.

4.3 Welding schedule

4.3.1 A welding schedule containing not less than the following information is to be submitted:

(a) Weld throat thickness or leg lengths.
(b) Grades, tempers and thicknesses of materials to be welded.
(c) Locations, types of joints and angles of abutting members.
(d) Reference to welding procedures to be used.
(e) Welded connections to steel castings.

4.4 Butt welds

4.4.1 All structural butt joints are to be made by means of full penetration welds and, in general, the edges of plates to be joined by welding are to be bevelled on one or both sides of the plates. Full details of the proposed joint preparation are to be included in the approval welding procedure.

4.4.2 Where butt welds form a T-junction, the leg of the T is, where practicable, to be completed first including any back run. During the welding operation special attention is to be given to the completion of the weld at the junction, which is to be chipped back to remove crater cracks, etc. before the table is welded.

4.4.3 For ships with shock enhanced notation, *see Vol 1, Pt 4, Ch 2, 4 Fragmentation protection*

4.5 Fillet welds

4.5.1 The throat thickness of fillet welds is to be determined from:

$$\text{Throat thickness} = t_{\text{p}} \times \text{weld factor} \times \left(\frac{d}{s}\right) \text{ mm}$$

where

s = the length of correctly proportioned weld fillet, clear of end craters, in mm, and is to be 10 x plate thickness, t_{p}, or 75 mm, whichever is the lesser, but in no case to be taken less than 40 mm

d = the distance between successive weld fillet, in mm

t_{p} = plate thickness, in mm, on which weld fillet size is based, *see Vol 1, Pt 6, Ch 6, 4.5 Fillet welds 4.5.4*

Weld factors are contained in *Table 6.4.1 Weld factors* and *Figure 6.4.1 Weld fillet dimensions*

NOTE: for double continuous fillet welding $\left(\frac{d}{s}\right)$ is to be taken

as 1, *see Vol 1, Pt 6, Ch 6, 4.8 Double continuous fillet welding 4.8.1*.

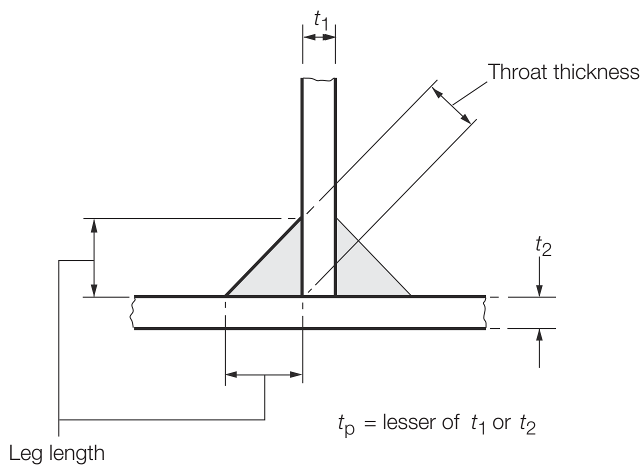


Figure 6.4.1 Weld fillet dimensions

4.5.2 For ease of welding, it is recommended that the ratio of the web height to the flange breadth is greater than or equal to 1,5, *see Figure 6.4.2 Web height/flange breadth ratio*

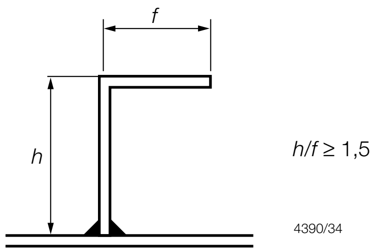


Figure 6.4.2 Web height/flange breadth ratio

4.5.3 The leg length of the weld is to be not less than $\sqrt{2}$ times the specified throat thickness.

4.5.4 The plate thickness t_p to be used in *Vol 1, Pt 6, Ch 6, 4.5 Fillet welds 4.5.1* is generally to be that of the thinner of the two parts being joined. Where the difference in thickness is considerable, the size of fillet weld will be specially considered.

4.5.5 Where the thickness of the abutting member of the connection (e.g. the web of a stiffener) is greater than 15 mm and exceeds the thickness of the table member (e.g. plating), the welding is to be double continuous and the throat thickness of the weld is to be not less than the greatest of the following:

(a) 0,21 x thickness of the table member. The table member thickness used need not exceed 30 mm.
(b) 0,21 (0,27 in tanks) x half the thickness of the abutting member.
(c) As required by item 3 in *Table 6.4.2 Throat thickness limits*

Table 6.4.1 Weld factors

Item		Weld factor	Remarks
(1)	General application:		except as required below
	Watertight plate boundaries	0,34	
	Non-tight plate boundaries	0,13	
	Longitudinals, frames, beams, and other secondary members to shell, deck or bulkhead plating	0,10	
		0,13	in tanks in way of end connections
		0,21	
	Panel stiffeners, etc.	0,10	
	Overlap welds generally	0,27	
	Longitudinals of the flat-bar type to plating		*See Vol 1, Pt 6, Ch 6, 4.5 Fillet welds 4.5.5*

(2) Bottom construction in way of tanks:		
Non-tight centre girder:		
to keel	0,27	
to inner bottom	0,21	no scallops
Non-tight boundaries of floors, girders and brackets	0,21 0,27	in way of 0,2 x span at ends in way of brackets at lower end of main frame
Inner bottom longitudinals or reverse frames	0,13	
Connection of floors to inner bottom in way of bulkheads, supported on inner bottom. The supporting floors are to be continuously welded to the inner bottom	0,44	weld size based on floor thickness weld material compatible with floor material
(3) Hull framing:		
Webs of web frames and stringers:		
to shell	0,16	
to face plate	0,13	
Tank side brackets to shell and inner bottom	0,34	
(4) Decks and supporting structure:		
Strength deck plating to shell		as shown in *Table 6.4.5 Weld connection of strength deck plating to sheerstrake* but alternative proposals will be considered
Other decks to shell and bulkheads (except where forming tank boundaries)	0,21	generally continuous
Webs of cantilevers to deck and to shell in way of root bracket	0,44	
Webs of cantilevers to face plate	0,21	
Pillars: fabricated	0,10	
end connections	0,34	*see* Note
end connections (tubular)	full penetration	
Girder web connections and brackets in way of pillar heads and heels and end brackets	0,21	continuous
Girder web connections general	0,1	
(5) Bulkheads and tank construction:		
Plane, double plate and corrugated watertight bulkhead boundary at bottom, bilge, inner bottom, deck and connection to shelf plate, where fitted	0,44	Weld size to be based on thickness of bulkhead platingWeld material to be compatible with bulkhead plating material
Shelf plate connection to stool	0,44	Weld size to be based on thickness of stool at junction with shelf plate. Weld material to be compatible with stool material
Plane, double plate and corrugated main watertight bulkhead boundaries	0,44	
– Boundary at bottom, bilge, inner bottom and deck		

	– Connection of bulkhead plating to side shell	0,44	
	Deep tank horizontal boundaries at vertical corrugations	Full penetration	
	Secondary members where acting as pillars	0,13	
	Non-watertight pillar bulkhead boundaries	0,13	
	Perforated flats and wash bulkhead boundaries	0,10	
(6)	Structure in machinery space:		
	Centre girder to keel and inner bottom	0,27	no scallops to inner bottom
	Floors to centre girder in way of engine, thrust and boiler bearers	0,27	
	Floors and girders to shell and inner bottom	0,21	
	Main engine foundation girders:		
	to top plate to hull structure	deep penetration to depend on design	edge to be prepared with maximum root 0,33tp deep penetration generally
	Floors to main engine foundation girders	0,27	
	Brackets, etc. to main engine foundation girders	0,21	
	Transverse and longitudinal framing to shell	0,13	
(7)	Construction forward 0,75L_R:		
	Floors and girders to shell and inner bottom	0,21	
	Bottom longitudinals to shell	0,13	
	Transverse and longitudinal side framing to shell	0,13	
	Tank side brackets to frame and inner bottom	0,34	
	Panting stringers to shell and frames	0,34	
	Fore peak construction:		
	all internal structure	0,13	unless a greater weld factor is required
(8)	After peak construction:		
	All internal structure and stiffeners on afterpeak bulkhead	0,21	unless a greater weld factor is required
(9)	Superstructure and deckhouses:		
	Connection of external bulkheads to deck	0,34	1st and 2nd tier erections
		0,21	elsewhere
	Internal bulkheads	0,13	
(10)	Steering control systems:		
	Rudder:		
	Fabricated mainpiece and mainpiece to side plates and webs	0,44	
	Slot welds inside plates	0,44	
	Remaining construction	0,21	
	Fixed and steering nozzles:		
	Main structure	0,44	

	Elsewhere	0,21	
	Fabricated housing and structure of thruster units, stabilisers, etc.:		
	Main structure	0,44	
	Elsewhere	0,21	
(11)	Miscellaneous fittings and equipment:		
	Rings for manhole type covers, to deck or bulkhead	0,34	
	Frames of shell and weathertight bulkhead doors	0,34	
	Stiffening of doors	0,21	
	Ventilator, air pipe, etc. coamings to deck	0,34	
	Ventilator, etc. fittings	0,21	
	Scuppers and discharges, to deck	0,44	
	Masts, derrick posts, crane pedestals, etc. to deck	0,44	full penetration welding may be required
	Deck machinery seats to deck	0,21	generally
	Mooring equipment seats	0,21	generally, but increased or full penetration welding may be required
	Bulwark stays to deck	0,21	
	Bulwark attachment to deck	0,34	
	Guard rails, stanchions, etc. to deck	0,34	
	Bilge keel ground bars to shell	0,34	Continuous fillet weld, minimum throat thickness 4 mm
	Bilge keels to ground bars	0,21	Continuous fillet weld,minimum throat thickness 3 mm
	Fabricated anchors	full penetration	
	Raft seatings	0,27	
	Weapon seatings	0,44	full penetration welding may be required
Note Where pillars are fitted inside tanks or under watertight flats, the end connection is to be such that the tensile stress in the weld does not exceed 108 N/mm^2.			

Table 6.4.2 Throat thickness limits

Item		Throat thickness, in mm	
		Minimum	Maximum
(1)	Double continuous welding	$0{,}21t_p$	$0{,}44t_p$
(2)	Intermittent welding	$0{,}27t_p$	$0{,}44t_p$or 4,5

(3)	All welds, overriding minimum:(a) Plate thickness $t_p \leq$ 7,5 mmHand or automatic weldingAutomatic deep penetrationwelding	3,0 3,0	- -
	(b) Plate thickness t_p > 7,5 mmHand or automatic weldingAutomatic deep penetrationwelding	3,25 3,0	- -
Note 1. In all cases, the limiting value is to be taken as the greatest of the applicable values given above. Note 2. Where t_p exceeds 25 mm, the limiting values may be calculated using a notional thickness equal to 0,5 (t_p + 25) mm. Note 3. The maximum throat thicknesses shown are intended only as a design limit for the approval of fillet welded joints. Any welding in excess of these limits is to be to the Surveyor's satisfaction.			

4.6 Throat thickness limits

4.6.1 The throat thickness limits given in *Table 6.4.2 Throat thickness limits* are to be complied with.

4.7 Single sided welding

4.7.1 Where the main welding is carried out from one side only, this should be in accordance with the approved single sided welding procedure.

4.7.2 Where internal access for welding is impracticable, backing bars are to be fitted in way of butt welds, or alternative means of obtaining full penetration welds are to be agreed. Backing bars may be permanent or temporary, subject to agreement.

4.7.3 Permanent backing bars are to be of the same material as the base metal and of thickness not less than the thickness of the plating being joined or 4 mm, whichever is the lesser. The weld is to be thoroughly fused to the backing bar, subject to agreement.

4.7.4 Backing bars are to be continuous for the full length of the weld and joints in the backing bar are to be by full penetration welds, ground smooth.

4.7.5 Temporary backing bars for single sided welding may be glass tape, ceramic, or steel of the same grade as the base metal.

4.7.6 Temporary non-metallic backing bars are to be suitably grooved in way of the weld to ensure full penetration.

4.8 Double continuous fillet welding

4.8.1 Where double continuous fillet welding is proposed the throat thickness is to be in accordance with *Vol 1, Pt 6, Ch 6, 4.5 Fillet welds 4.5.1* taking *d/s* equal to 1.

4.8.2 Double continuous fillet welding is to be adopted in the following locations and may be used elsewhere if desired:

(a) Boundaries of weathertight decks and erections and all other openings.
(b) Boundaries of tank and watertight compartments.
(c) Main engine and equipment seatings and rafts.
(d) Bottom framing structure in machinery spaces of high speed ships.
(e) The side and bottom shell structure in the impact area of high speed ships.
(f) Structure in way of rudders, propeller brackets, stabilisers, thrusters, bilge keels, foundations and other areas subject to high stresses.
(g) The shell structure in the vicinity of the propeller blades.
(h) Stiffening members to plating in way of end connections scallops and of end brackets to plating in the case of lap connections.
(i) Face flats to webs of built-up/fabricated stiffening members in way of knees/end brackets and for a distance beyond such knees/end brackets of not less than the web depth of stiffener in way.
(j) All structure in the after peak and after peak bulkhead stiffeners.
(k) Forward tanks.
(l) Lap welds in tanks.
(m) Primary and secondary members to bottom shell forward of 0,7*L*.
(n) Where *Vol 1, Pt 6, Ch 6, 4.5 Fillet welds 4.5.5* applies.

(o) Other connections or attachments where necessary in particular minor items to high tensile steel plating.

4.9 Intermittent and single sided fillet welding

4.9.1 The requirements for intermittent fillet welding (staggered and chain) are given in *Figure 6.4.1 Weld fillet dimensions*

4.9.2 As an alternative to intermittent welding, single sided welding may be used. Only mechanised single sided welding is acceptable.

4.9.3 Where staggered intermittent or single sided fillet welding is used, the welding is to be made continuous round the ends of brackets, lugs, scallops, etc.

4.9.4 Staggered intermittent or single sided fillet welding is not to be used in the bottom shell structure of high speed ships.

4.9.5 Chain intermittent welding may be used, outside of the impact area in the bottom shell structure of high speed ships.

4.9.6 Scalloped construction, intermittent or single sided fillet welding is not to be used in structure on or below the strength deck of ships with shock enhancement or in structure strengthened for blast enhancement, *see Vol 1, Pt 4, Ch 2 Military Load Specification*.

4.9.7 Scalloped construction, intermittent or single sided fillet welding is not to be used in structure complying with the requirements of the internal blast station.

4.9.8 For ships with a shock enhanced notation, the extent of intermittent or single sided fillet welding will be specially considered on the basis of the threat levels

4.10 Connections of primary structure

4.10.1 Weld factors for the connections of primary structure are given in *Table 6.4.3 Connections of primary structure*.

Table 6.4.3 Connections of primary structure

Primary member face area, in cm^2		Position(1)	Weld factor			
			In tanks		In dry spaces	
Exceeding	Not exceeding		To face plate	To plating	To face plate	To plating
	30,0	At ends	0,21	0,27	0,21	0,21
		Remainder	0,10	0,16	0,10	0,13
30,0	65,0	At ends	0,21	0,34	0,21	0,21
		Remainder	0,13	0,27	0,13	0,16
65,0	95,0	At ends	0,34	0,44(3)	0,21	0,27
		Remainder	0,27(2)	0,34	0,16	0,21
95,0	130,0	At ends	0,34	0,44(3)	0,27	0,34
		Remainder	0,27(2)	0,34	0,21	0,27
130,0		At ends	0,44	0,44(3)	0,34	0,44(2)
		Remainder	0,34	0,34	0,27	0,34

Note 1. The weld factors ‘at ends’ are to be applied for 0,2 x the overall length of the member from each end, but at least beyond the toes of the member end brackets. On vertical webs the increased welding may be omitted at the top, but is to extend at least 0,3 x overall length from the bottom.

Note 2. Where the web plate thickness is increased locally, the weld size may be based on the thickness clear of the increase, but is to be not less than 0,34 x the increased thickness.

Note 3. The weld factor of the connection of bottom transverses to shell, and of side transverses to shell and vertical webs to longitudinal and transverse bulkheads all in the lower half depth, is to be not less than 0,34.

Note 4. The final throat thickness of the weld fillet to be not less than $0{,}34 t_p$ in oil tanks.

4.10.2 The weld connection to shell, deck or bulkhead is to take account of the material lost in the notch where longitudinals or stiffeners pass through the member. Where the width of notch exceeds 15 per cent of the stiffener spacing, the weld factor is to be multiplied by:

$$\frac{0,85 \times \text{ stiffener spacing}}{\text{length of web plating between notches}}$$

4.10.3 Where direct calculation procedures have been adopted, the weld factors for the 0,2 x overall length at the ends of the members will be considered in relation to the calculated loads.

4.10.4 The throat thickness limits given in *Table 6.4.2 Throat thickness limits* are to be complied with.

4.10.5 Where a margin angle is not fitted the sheerstrake connection is to be in accordance with *Table 6.4.5 Weld connection of strength deck plating to sheerstrake*

4.11 Primary and secondary member end connection welds

4.11.1 Welding of end connections of primary members is to be such that the area of welding is not less than the cross-sectional area of the member, and the weld factor is to be not less than 0,34 in tanks or 0,27 elsewhere.

4.11.2 The welding of secondary member end connections is to be not less than as required by *Table 6.4.4 Primary and secondary member end connection welds* Where two requirements are given, the greater is to be complied with.

4.11.3 The area of weld, A_w, is to be applied to each arm of the bracket or lapped connection.

4.11.4 Where a longitudinal strength member is cut at a primary support and the continuity of strength is provided by brackets, the area of weld is to be not less than the crosssectional area of the member.

4.11.5 The scantlings of brackets are to be in accordance with *Vol 1, Pt 6 Hull Construction in Steel*, as appropriate.

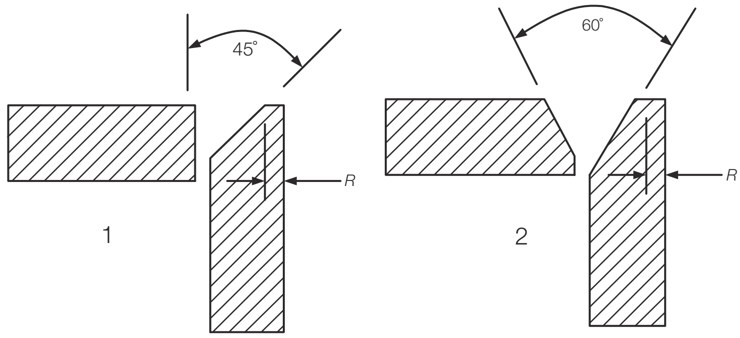
4.11.6 The throat thickness limits given in *Table 6.4.2 Throat thickness limits* are to be complied with.

Table 6.4.4 Primary and secondary member end connection welds

	Connection	Weld area, A_w, in cm^2	Weld factor
(1)	Stiffener welded direct to plating	0,25A_s or 6,5 cm^{2}whichever is the greater	0,34
(2)	Bracketless connection of stiffeners or stiffener lapped to bracket or bracket lapped to stiffener:(a) in dry space(b) in tank(c) in 0,15*L* forward	1,2 $\sqrt{Z}$ 1,4 $\sqrt{Z}$ as (a) or (b)	0,270,34 0,34
(3)	Bracket welded to face of stiffener and bracket connection to plating	—	0,34
(4)	Stiffener to plating for 0,1 x span at ends, or in way of end bracket if that be greater	—	0,34
Symbols			
A_s = cross-sectional area of the stiffener, in cm^2 A_w = the area of the weld, in cm^2, and is calculated as total length of weld, in cm, x throat thickness, in cm Z = the section modulus, in cm^2, of the stiffener on which the scantlings of the bracket are based.			
Note For maximum and minimum weld fillet sizes, *see Table 6.4.2 Throat thickness limits*.			

Table 6.4.5 Weld connection of strength deck plating to sheerstrake

Item	Stringerplate thickness,mm	Weld type
1	$t \leq 15$	Single vee preparation to provide included angle of 45° with root $R \leq 1/3\ t$ in conjunction with a continuous fillet weld having a weld factor of 0,39
2	$15 < t \leq 25$	Double vee preparation to provide included angle of 60° with root $R \leq 1/3\ t$ in conjunction with a continuous fillet weld having a weld factor of 0,39
3	$t > 25$	Triple vee preparation to provide included angles of 50° with root $R \leq 1/3\ t$ but not to exceed 10 mm



Note 1 Welding procedure, including joint preparation, is to be specified. Procedure is to be qualified and approved for individual Builders.

Note 2 *See also Vol 1, Pt 6, Ch 6, 4.13 Intersection of primary and secondary members 4.13.1*.

Note 3 For thickness t in excess of 20 mm the stringer plate may be bevelled to achieve a reduced thickness at the weld connection. The length of the bevel is in general to be based on a taper not exceeding 1 in 3 and the reduced thickness is in general to be not less than 0,65 times the thickness of stringer plate or 20 mm, whichever is the greater.

Note 4 Alternative connections will be considered.

4.12 Tank boundary penetrations

4.12.1 Where structural members pass through the boundary of a tank, and leakage into the adjacent space could be hazardous or undesirable, full penetration welding is to be adopted for the members for at least 150 mm on each side of the boundary. Alternatively a small scallop of suitable shape may be cut in the member close to the boundary outside the compartment, and carefully welded all round.

4.13 Intersection of primary and secondary members

4.13.1 The weld area of the connections is to be generally not less than the following:

(a) Connection of primary member stiffener to the secondary member:

A_w = $0{,}25A_f$ or 6,5 cm^2, whichever is the greater, corresponding to a weld factor of 0,34 for the throat thickness

(b) Connection of secondary member to the web of the primary member:

A_w = $0{,}5\sqrt{Z}$ corresponding to a weld factor of 0,34 in tanks or 0,27 in dry spaces for the throat thickness.

where

A_w = weld area, in cm^2, and is calculated as total length of weld, in cm, multiplied by throat thickness, in cm

A_f = cross-sectional area of the primary member web stiffener, in cm^2, in way of connection

Z = the section modulus, in cm^3, of the secondary member.

■ *Section 5*
Construction details

5.1 Continuity and alignment

5.1.1 Continuity is to be maintained where primary members intersect and where the members are of the same depth, a suitable gusset plate or brackets are to be fitted, *see Figure 6.5.1 Primary member intersection*

5.1.2 The toes of brackets, etc. are not to land on unstiffened panels of plating. Special care is to be taken to avoid notch effects at the toes of brackets, by making the toe concave or otherwise tapering it off.

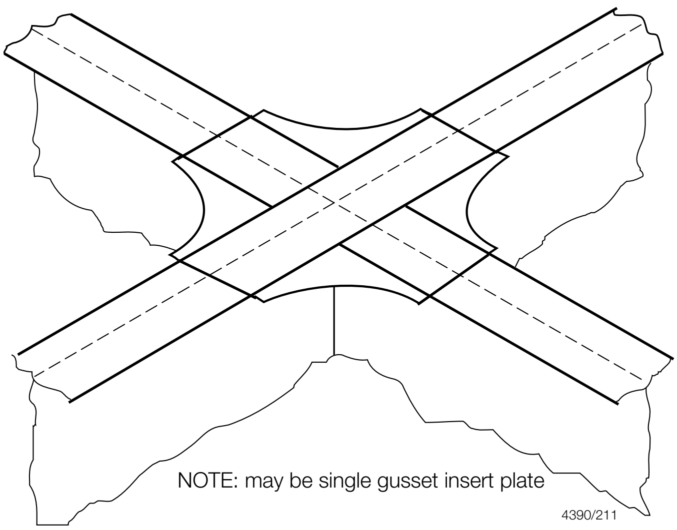


Figure 6.5.1 Primary member intersection

5.1.3 Particular care is to be paid to the design of the end bracket toes in order to minimise stress concentrations. Sniped face plates which are welded onto the edge of primary member brackets are to be carried well around the radiuses bracket toe and are to incorporate a taper not exceeding one in three. Where sniped face plates are welded adjacent to the edge of primary member brackets, adequate cross-sectional area is to be provided through the bracket toe at the end of the snipe. In general, this area measured perpendicular to the face plate, is to be not less than 60 per cent of the full cross-sectional area of the face plate, *see Figure 6.5.2 Bracket toe construction*

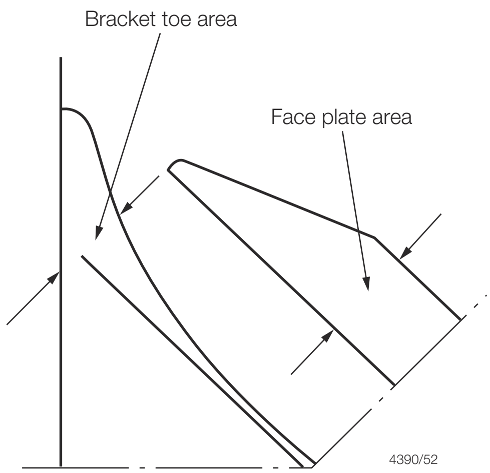


Figure 6.5.2 Bracket toe construction

5.2 Primary end connections

5.2.1 The requirements for section modulus and inertia (if applicable) of primary members are given in the appropriate Chapter. The scantling requirements for primary member end connections in dry spaces and in tanks of all ship types are generally to comply with the requirements of *Vol 1, Pt 6, Ch 2 Design Tools*,*Vol 1, Pt 6, Ch 3 Scantling Determination*, taking *Z* as the section modulus of the primary member.

5.2.2 Guidance on the arrangement of primary stiffeners is given in *Vol 1, Pt 3, Ch 2, 3.2 Primary members*

5.2.3 Connections between primary members forming ring system are to minimise stress concentrations at the junctions. Integral brackets are generally to be radiused or well rounded at their toes. The arm length of the bracket, measured from the face of the member, is to be not less than the depth of the smaller member forming the connection.

5.2.4 The requirements of this Section may be modified where direct calculation procedures are adopted to analyse the stress distribution in the primary structure.

5.2.5 The geometric properties of the members are to be calculated in association with an effective width of attached plating determined in accordance with *Vol 1, Pt 6, Ch 2, 2.2 Effective width of attached plating, be*

5.2.6 The minimum thickness or area of material in each component part of the primary member is given in *Table 6.5.1 Minimum thickness of primary members*.

Table 6.5.1 Minimum thickness of primary members

Item		Requirement
(1)	Member web plate (*see* Note)	$t_w = 0{,}01 S_w$ but not less than 6 mm in dry spaces and not less than 7 mm in tanks
(2)	Member face plate	A_f not to exceed $\dfrac{d_w t_w}{150}$ cm^2
(3)	Deck plating forming the upper flange of underdeck girders	Plate thickness not less than $\sqrt{\dfrac{A_f}{1,8k}}$ mm
Symbols		

d_w	=	depth of member web, in mm
k	=	higher tensile steel factor, *see Vol 1, Pt 6, Ch 2 Design Tools*
t_w	=	thickness of member web, in mm
A_f	=	area of member face plate or flange, in cm^2
S_w	=	spacing of stiffeners on member web, or depth of unstiffened web, in mm

Note For primary members having a web depth exceeding 1500 mm, the arrangement of stiffeners will be individually considered, and stiffening parallel to the member face plate may be required.

5.3 Secondary member end connections

5.3.1 Secondary members, that is longitudinals, beams, frames and bulkhead stiffeners forming part of the hull structure, are to be effectively continuous and are to be suitably bracketed at their end connections. Where it is desired to adopt bracketless connections, the proposed arrangements will be individually considered, *see also Table 6.4.3 Connections of primary structure*.

5.3.2 Where bracketed end connections are fitted in accordance with these requirements, they may be taken into account in determining the effective span of the member.

5.3.3 The scantlings of secondary member end connections are to be in accordance with *Vol 1, Pt 6, Ch 6, 5.4 Scantlings of end brackets*.

5.4 Scantlings of end brackets

5.4.1 For a naval ship, longitudinal strength members are to be continuous through primary supports. In exceptional cases for ships having a military distinction notation **MD** and in areas not subject to significant fatigue loading, longitudinal strength members may be cut at a primary support and the continuity of strength is to be provided by brackets. In such cases the scantlings of the brackets are to be such that their section modulus and effective cross-sectional area are not less than those of the member. Care is to be taken to ensure correct alignment of the brackets on each side of the primary member.

5.4.2 In other cases the scantlings of the bracket are to be based on the modulus as follows:

(a) Bracket connecting stiffener to primary member – modulus of the stiffener.
(b) Bracket at the head of a main transverse frame where frame terminates – modulus of the frame.
(c) Brackets connecting lower deck beams or longitudinals to the main frame in the forward $0,5L_R$ – modulus of the frame.
(d) Elsewhere – the lesser modulus of the members being connected by the bracket.

5.4.3 The web thickness and face flat area of end brackets are not in general to be less than those of the connecting stiffeners. Additionally, the stiffener proportion requirements of *Vol 1, Pt 6, Ch 2, 2.9 Proportions of stiffener sections* are to be satisfied.

5.4.4 Typical arrangements of stiffener end brackets are shown diagrammatically in *Figure 6.5.3 Stiffener end brackets*.

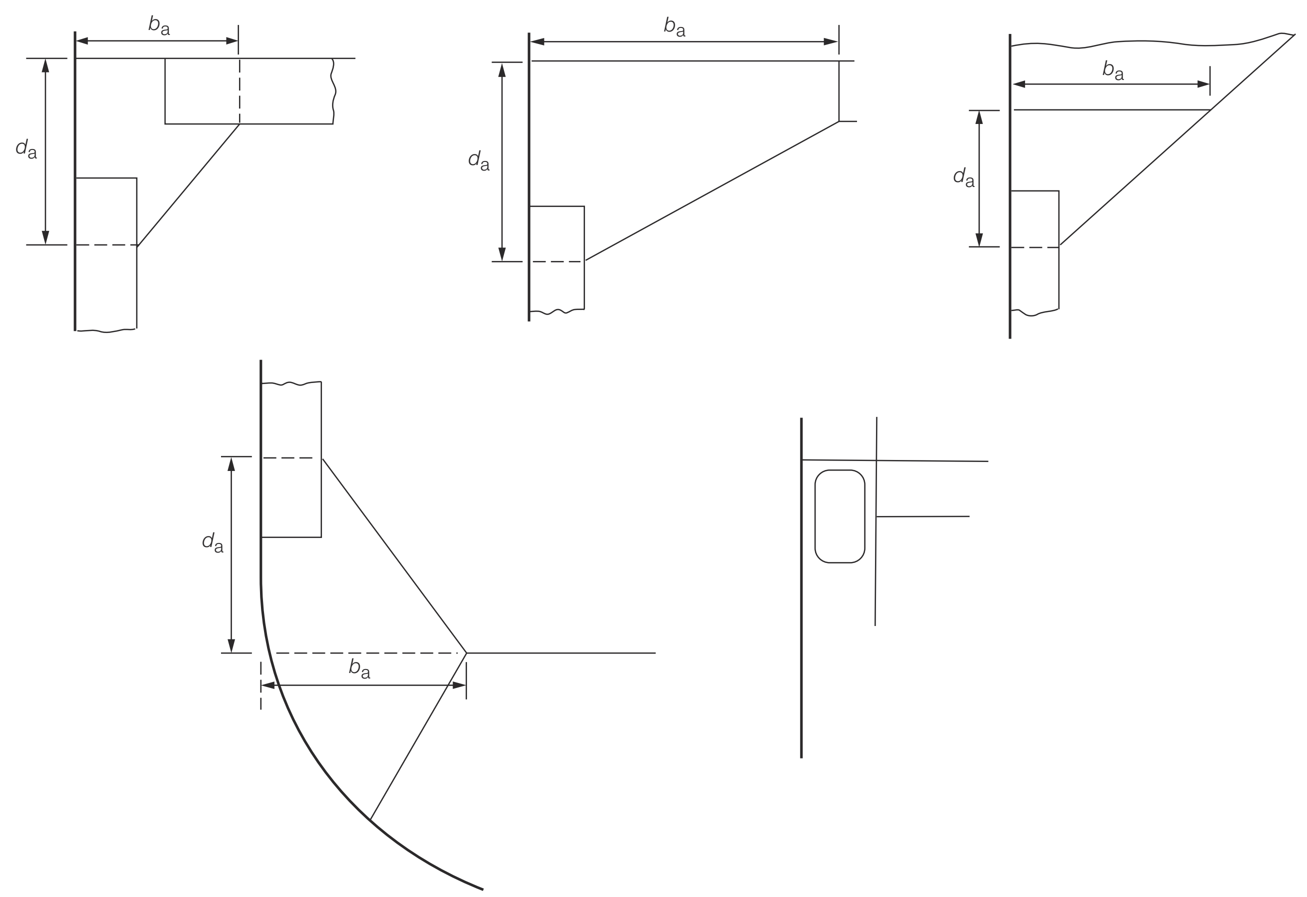


Figure 6.5.3 Stiffener end brackets

5.4.5 The lengths, d_a and b_a, of the arms are to be measured from the plating to the toe of the bracket and are to be such that:

(a) $d_a + b_a \geq 2{,}0 l_b$
(b) $d_a \geq 0{,}8 l_b$
(c) $b_a \geq 0{,}8 l_b$

where

a and *b* are the actual lengths of the two arms of the bracket, in mm, measured from the plating to the toe of the bracket

$$l_b = 90\left(2\sqrt{\frac{Z}{14+\sqrt{Z}}}-1\right) \text{ mm}$$

Z = the section modulus of the secondary member, in cm^3. In no case is l_b to be taken as less than twice the web depth of the stiffener on which the bracket scantlings are to be based.

5.4.6 The scantlings of deep web frames are based on the inclusion of the standard brackets specified in *Vol 1, Pt 6, Ch 6, 5.4 Scantlings of end brackets 5.4.5* at top and bottom, while the scantlings of side frames are normally to be based on a standard bracket at the top only. Where the actual arm lengths fitted, d_{a1}, and b_{a1} (in mm) are smaller than Rule size above or the bracket is omitted then, for comparison purposes, an equivalent arm length, l_a, is to be derived from:

(a) $$l_a = \frac{(d_{a1} + b_{a1})}{2}$$

(b) $d_{a1} \geq 0{,}8 l_a$

(c) $b_{a1} \geq 0{,}8 l_a$
(d) $l_a = 0$

where

(i) bracket is omitted from the upper or lower ends of the frame, or
(ii) lower frame bracket at bilge is at same level as the inner bottom, or
(iii) lower frame is welded directly to the inner bottom.

5.4.7 The free edge of the bracket is to be stiffened where any of the following apply:

(a) The section modulus, Z, exceeds 2000 cm^3.
(b) The length of free edge exceeds 50 times the bracket thickness.
(c) The bracket is fitted at the lower end of main transverse side framing.

5.4.8 Where a face flat is fitted, its breadth, b_f, is to be not less than:

$$b_\mathrm{f} = 40\left(1 + \frac{z}{1000}\right) \text{ mm but not less than 50 mm.}$$

5.4.9 Where the edge is stiffened by a welded face flat, the cross-sectional area of the face flat is to be not less than:

(a) $0{,}009 k_s b_f t_b$ cm^2 for offset edge stiffening.
(b) $0{,}014 k_s b_f t_b$ cm^2 for symmetrically placed stiffening.

b_f = breadth of face flat, in mm

t_b = the thickness of the bracket, in mm k_s is as defined in *Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*.

5.4.10 Where the stiffening member is lapped on to the bracket, the length of overlap is to be adequate to provide for the required area of welding. In general, the length of overlap is not to be less than $10\sqrt{Z}$ mm , or the depth of stiffener, whichever is the greater.

5.4.11 Where the free edge of the bracket is hollowed out, it is to be stiffened or increased in size to ensure that the modulus of the bracket through the throat is not less than that of the required straight edged bracket.

5.4.12 The arrangement of the connection between the stiffener and the bracket is to be such that at no point in the connection is the actual modulus reduced to less than that of the stiffener with associated plating.

5.4.13 The design of end connections and their supporting structure is to be such as to provide adequate resistance to rotation and displacement of the joint.

5.4.14 The thickness of the bracket is to be not less than as required by *Table 6.5.2 Thickness of end brackets*.

Table 6.5.2 Thickness of end brackets

Bracket		Thickness, in mm	LImits	
			Minimum, in mm	Maximum, in mm
With edge stiffened:				
(a)	in dry spaces	$3{,}5 + 0{,}25\sqrt{Z}$	6,5	12,5
(b)	in deep tanks	$4{,}5 + 0{,}25\sqrt{Z}$	7,5	13,5
Unstiffened brackets:				
(a)	in dry spaces	$5{,}5 + \left(\frac{Z}{55}\right) - \left(\frac{Z}{168}\right)^{1/3}$	7,5	
(b)	in deep tanks	$6{,}5 + \left(\frac{Z}{55}\right) - \left(\frac{Z}{168}\right)^{1/3}$	8,5	

5.5 Arrangement at intersection of primary and secondary members

5.5.1 Lugs or tripping brackets are to be fitted where shell longitudinals are continuous through web frames in way of highly stressed areas of the side shell (e.g. in way of equipment supports, bollards, fenders, etc.).

5.5.2 Lugs or tripping brackets are also to be fitted where continuous secondary stiffeners are greater than half the depth of the primary stiffeners.

5.5.3 Cut-outs in primary members are to comply with the requirements of *Vol 1, Pt 3, Ch 2, 3.2 Primary members 3.2.11*and *Vol 1, Pt 3, Ch 2, 3.2 Primary members 3.2.12*

5.5.4 Cut-outs for the passage of secondary members through the webs of primary members, and the related collaring arrangements, are to be designed to minimise stress concentrations around the perimeter of the opening and in the attached hull envelope or bulkhead plating. The critical shear buckling stress of the panel in which the cut-out is made is to be investigated. Cut-outs for longitudinals will be required to have double lugs in areas of high stress. Some typical lug connections are shown in *Figure 6.5.4 Typical lug connections* and *Figure 6.5.5 Cut-out and connections*, *see Vol 1, Pt 6, Ch 6, 5.5 Arrangement at intersection of primary and secondary members 5.5.12*

5.5.5 The breadth of cut-outs is to be as small as practicable, with the top edge suitably radiused. Cut-outs are to have smooth edges, and the corner radii are to be as large as practicable, with a minimum of 20 per cent of the breadth of the cut-out or 20 mm, whichever is the greater. For large cut-outs greater than 250 mm deep, it is recommended that the web plate connection to the hull envelope, or bulkhead, end in a smooth tapered 'soft toe'. Recommended shapes of cut-out are shown in *Figure 6.5.4 Typical lug connections*, but consideration will be given to other shapes on the basis of maintaining equivalent strength and minimising stress concentration.

5.5.6 Consideration is to be given to the provision of adequate drainage and unimpeded flow of air and water when designing the cut-outs and connection details.

5.5.7 Asymmetrical secondary members are to be connected on the heel side to the primary member web plate. Additional connection by lugs on the opposite side may be required.

5.5.8 Symmetrical secondary members are to be connected by lugs on one or both sides, as necessary.

5.5.9 Where a bracket is fitted to the primary member web plate in addition to a connected stiffener it is to be arranged on the opposite side to, and in alignment with the stiffener. The arm length of the bracket is to be not less than the depth of the stiffener, and its cross-sectional area through the throat of the bracket is to be included in the calculation of A_f, *see Vol 1, Pt 6, Ch 6, 4.13 Intersection of primary and secondary members 4.13.1*.

5.5.10 In general where the primary member stiffener is connected to the secondary member it is to be aligned with the web of the secondary member, except where the face plate of the latter is offset and abutted to the web, in which case the stiffener connection is to be lapped. Lapped connections of primary member stiffeners to mild steel bulb plate or rolled angle secondary members may also be permitted. Where such lapped connections are fitted, particular care is to be taken to ensure that the primary member stiffener wrap around weld connection is free from undercut and notches.

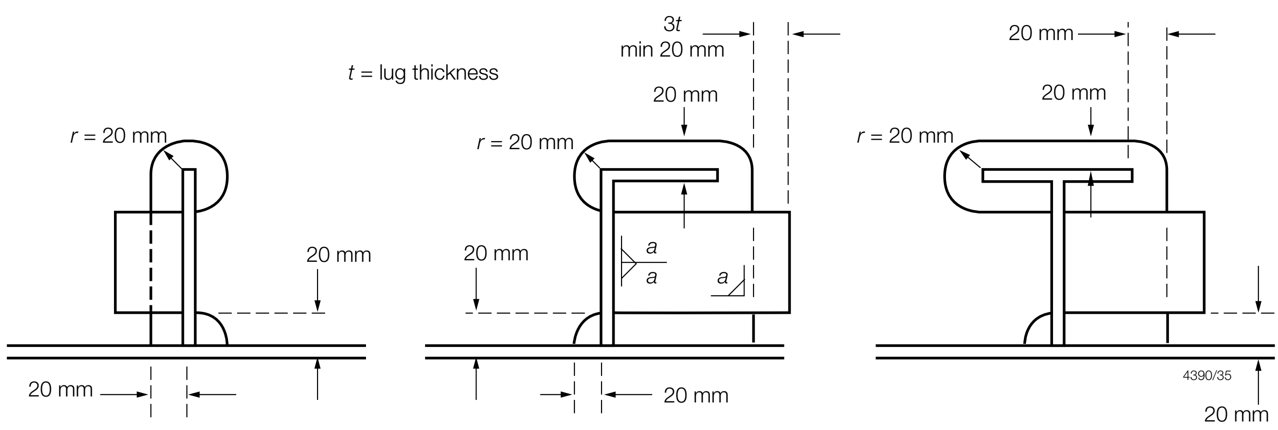


Figure 6.5.4 Typical lug connections

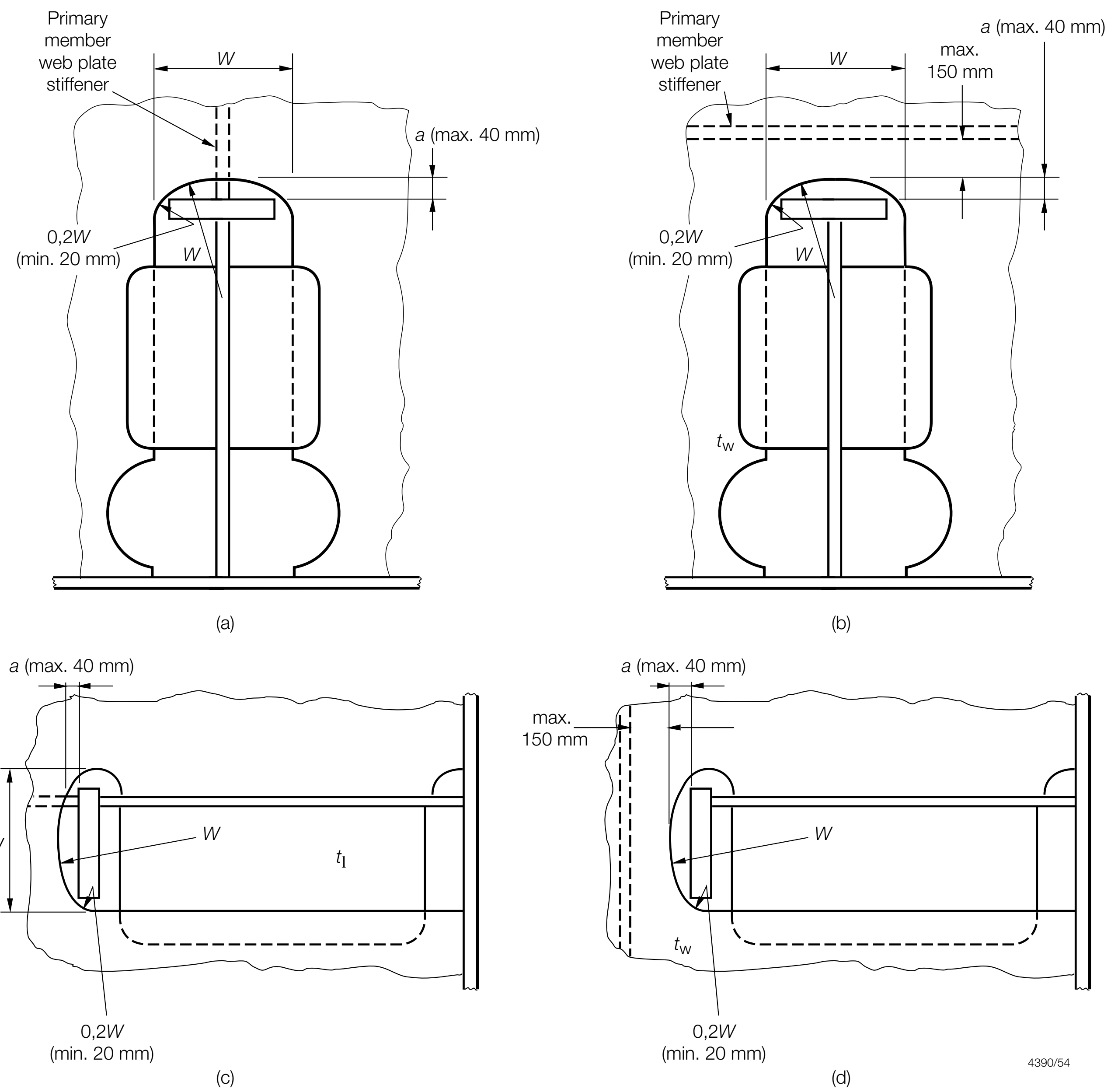


Figure 6.5.5 Cut-out and connections

5.5.11 Fabricated longitudinals having the face plate welded to the underside of the web, leaving the edge of the web exposed, are not recommended for side shell and longitudinal bulkhead longitudinals. Where it is proposed to fit such sections, a symmetrical arrangement of connection to transverse members is to be incorporated. This can be achieved by fitting backing brackets on the opposite side of the transverse web or bulkhead. The primary member stiffener and backing brackets are to be lapped to the longitudinal web, *see Vol 1, Pt 6, Ch 6, 5.5 Arrangement at intersection of primary and secondary members 5.5.10*.

5.5.12 The cross-sectional areas of the connections are to be determined from the proportion of load transmitted through each component in association with the appropriate permissible stress given in *Table 6.5.2 Thickness of end brackets*

Table 6.5.3 Permissible stresses

Item	Direct stress N/mm	Shear stress N/mm
Primary web plate stiffener adjacent to connection with secondary member	157	—
Welded connection of primary member web plate stiffener to secondary member:		
Double continuous fillet	117,7	—
Automatic deep penetration	157	—
Lug or collar plate and weld connection	—	98,1

5.6 Arrangement with offset stiffener

5.6.1 Where the stiffeners of the double bottom floors and transverse bulkheads are unconnected to the secondary members and offset from them (*see Figure 6.5.6 Arrangement with offset stiffener*) the collar arrangement for the secondary members are to satisfy the requirements of *Vol 1, Pt 6, Ch 6, 5.5 Arrangement at intersection of primary and secondary members 5.5.4*. In addition, the fillet welds attaching the lugs to the secondary members are to be based on a weld factor of 0,44 for the throat thickness. To facilitate access for welding the offset stiffeners are to be located 50 mm from the slot edge furthest from the web of the secondary member. The ends of the offset stiffeners are to be suitably tapered and softened.

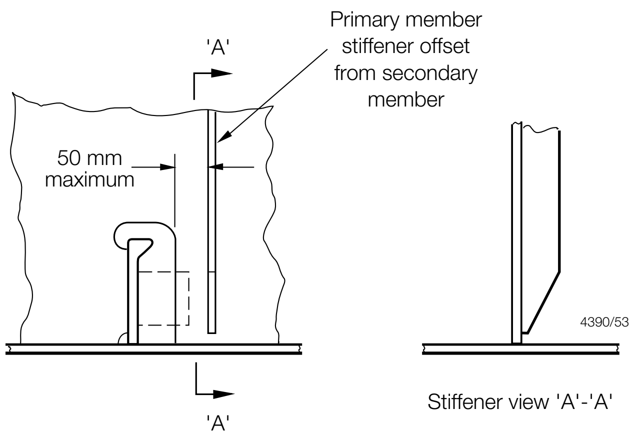


Figure 6.5.6 Arrangement with offset stiffener

5.6.2 Alternative arrangements will be considered on the basis of their ability to transmit load with equivalent effectiveness. Details of the calculations made and testing procedures are to be submitted.

5.6.3 For ships with shock enhancement notation, *see Vol 1, Pt 4, Ch 2, 4 Fragmentation protection*

5.7 Watertight collars

5.7.1 Watertight steel collars are to be fitted, where stiffeners are continuous through watertight or oiltight boundaries.

5.7.2 Watertight steel collars or equivalent are to be fitted at gastight boundary.

5.8 Insert plates

5.8.1 Where thick insert plates are butt welded to thin plates, the edge of the thick plate may require to be tapered. The slope of the taper is generally not to exceed one in three.

5.8.2 The corners of insert plates are generally to be suitably radiused.

5.8.3 For ships with shock enhancement, *see Vol 1, Pt 4, Ch 2 Military Load Specification*

5.9 Doubler plates

5.9.1 Doubler plates are to be avoided and are not to be fitted in areas where corrosion may be a problem and access for inspection and maintenance is limited.

5.9.2 Where doubler plates are fitted, they are to have well radiused corners and the perimeter is to be continuously welded. Large doubler plates are also to be suitably slot welded, the details of which are to be submitted for consideration.

5.10 Other fittings and attachments

5.10.1 Gutterway bars and spurnwaters are not to be welded to boundary angles, or within 100 mm of the deck edge.

5.10.2 Minor attachments, such as pipe clips, staging lugs and supports, are generally to be kept clear of toes of end brackets, corners of openings and similar areas of high stress. Where connected to asymmetrical stiffeners, the attachments may be in line with the web providing the fillet weld leg length is clear of the offset face plate or flange edge. Where this cannot be achieved the attachments are to be connected to the web, and in the case of flanged stiffeners they are to be kept at least 25 mm clear of the flange edge. On symmetrical stiffeners, they may be connected to the web or to the centreline of the face plate in line with the web.

5.10.3 Where necessary in the construction of the ship, lifting lugs may be welded to the hull plating but they are not to be slotted through.

5.11 Bilge keels and ground bars

5.11.1 Bilge keel plating is to be attached to the shell plating as shown in *Figure 6.5.7 Double plate bilge keel construction*. Butt and seam welds in shell plating and bilge keels are to be staggered by at least 100 mm.

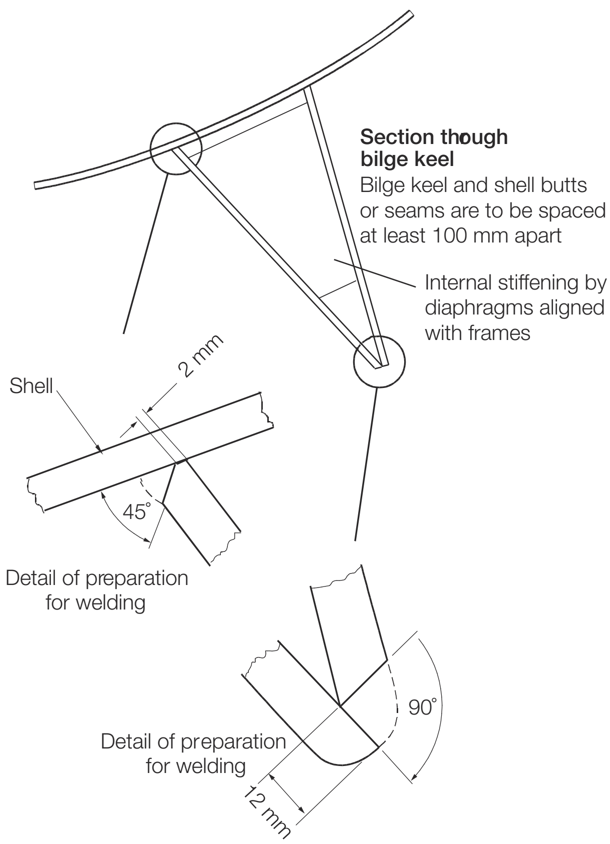


Figure 6.5.7 Double plate bilge keel construction

5.11.2 The shell plating in way of the bilge keel is to be at least grade D. Insert plates of 50 per cent greater thickness than the as fitted surrounding shell plate are to be fitted. They are to be greater than 300 x 300mm^2 with well rounded corners.

5.11.3 The thickness of the bilge keel is to be assessed using the appropriate scantling equation for shell envelope plating. To prevent possible damage to the shell, the bilge keel plate is not to be thicker than the adjacent shell plate. The material class, grade and quality of the bilge keel plating is to be the same as the adjacent shell plating, *see Table 6.2.1 Material classes and grades*.

5.11.4 Full continuous welding is to be used to connect the bilge keel to the shell.

5.11.5 The ends of the bilge keels are to have a 1 in 3 taper and terminate within 300 mm to 100 mm past an internal frame. Suitable internal framing is to be arranged in way of the ends of the bilge keels where, for hydrodynamic reasons, a steeper taper is necessary, the termination of the bilge keels will be especially considered.

5.11.6 For ships over 65 m in length, all welds are to be subject to non-destructive examination.

5.11.7 Bilge keels of an alternative design from that shown in *Figure 6.5.6 Arrangement with offset stiffener* with single plate construction or fitted with ground bars will be specially considered.

5.11.8 Internal stiffening is to be arranged in line with hull framing but is not to be attached to the shell plating.

5.11.9 Bilge keels are to be watertight and tested in accordance with *Vol 1, Pt 6, Ch 6, 6 Inspection and testing procedures*

5.11.10 The internal surfaces of the bilge keel and stiffening are to be suitably protected against corrosion.

5.12 Rivetting of light structure

5.12.1 Where it is proposed to adopt rivetted construction, full details of the rivets or similar fastenings, including mechanical test results, are to be indicated on the construction plans submitted for approval or a separate rivetting schedule is to be submitted.

5.12.2 Samples may be required of typical rivetted joints made by the Builder under representative construction conditions and tested to destruction in the presence of the Surveyor in shear, tension, compression or peel at LR's discretion.

5.12.3 Where rivetting strength data sheets have been issued by a recognised Authority, the values quoted in these sheets will normally be accepted for design purposes.

5.12.4 Where two dissimilar metals are to be joined by rivetting, precautions are to be taken to eliminate electrolytic corrosion to LR's satisfaction, and where practicable, the arrangements are to be such as to enable the joint to be kept under observation at each survey without undue removal of lining and other items.

5.12.5 Where a sealing compound is used to obtain an airtight or watertight joint, details are to be submitted of its proposed use and of any tests made or experience gained in its use for similar applications.

5.12.6 Sealing paints or compounds are not to be used with hot driven rivets.

5.13 Adhesive bonding of structure

5.13.1 Where adhesive bonding of any load-bearing structure is proposed, details of the materials and the processes to be used are to be submitted for approval. These details are to include test results of samples manufactured under LR survey under workshop conditions to verify the strength, ageing effects and moisture resistance of a typical joint.

5.13.2 The adhesive manufacturer's recommendations in respect of the specified jointing system, comprising preparation of the surfaces to be adhered, the adhesive, bonding and curing processes, are to be strictly followed as variation of any step can severely affect the performance of the joint.

5.13.3 Meticulous preparation is essential where the joint is to be made by chemical bonding. The method of producing bonded joints is to be documented so that the process is repeatable after the procedure has been properly established.

5.13.4 Bonded joints are suitable for carrying shear loads, but are not, in general, to be used in tension or where the load causes peeling or other forces tending to open the joint. Loads are to be carried over as large an area as possible.

5.13.5 Bonded joints are to be suitably supported after assembly for the period necessary to allow the optimum bond strength of the adhesive to be developed. Air pockets are to be avoided.

5.13.6 The use of adhesive for main structural joints is not to be contemplated unless considerable testing has established its validity, including environmental testing and fatigue testing where considered necessary by LR.

5.14 Triaxial stress considerations

5.14.1 Particular care is to be taken to avoid triaxial stresses which may result from poor joint design.

5.15 Aluminium/steel transition joints

5.15.1 Provision is made in this Section for bi-metallic composite aluminium/steel transition joints used for connecting aluminium structures to steel plating. Such joints are to be used in accordance with the manufacturer's requirements, *see also Ch 8, 4 Aluminium/steel transition joints* of the Rules for Materials.

5.15.2 Where a manufacturer is not approved, details of the materials to be used and the manufacturing procedures are to be submitted for approval before use.

5.15.3 Bimetallic joints where exposed to seawater or used internally within wet spaces are to be suitably protected to prevent galvanic corrosion.

5.15.4 Control of heat input is required when welding the transition joints to the steel structure in order to prevent disbondment.

5.16 Steel/wood connection

5.16.1 To minimise corrosion of steel when in contact with wood in a damp or marine environment the timber is to be primed and painted in accordance with good practice. Alternatively the surface of the steel in contact with the timber is to be coated with a substantial thickness of a suitable sealant.

■ *Section 6*
Inspection and testing procedures

6.1 General

6.1.1 A structural and leak test plan is to be submitted defining the compartments or tanks to be tested and the method of testing in accordance with the requirements of this Section.

6.1.2 Although referred to as watertight, some compartments or tanks may require to be tested as gastight or oil-tight.

6.1.3 The testing requirements for tanks, including independent tanks, watertight and weathertight compartments, are listed in *Table 6.6.1 Testing requirements*. Tests are to be carried out in the presence of the Surveyor at a stage sufficiently close to completion such that the strength and tightness are not subsequently impaired by subsequent work.

Table 6.6.1 Testing requirements

Item to be tested	Testing procedure	Installation testing requirement
Double bottom tanks	Structural (1)	The greater of: — head of water up to the top of the overflow — head of water representing the maximum pressure experienced in service for which elastic design criteria were used.
Cofferdams	Structural (1)	The greater of: — head of water up to the top of the overflow — 1,8 m head of water above highest point of tank (4)
Fore peak and after peak used as tank (3)	Structural	
Tank bulkheads	Structural (1)	The greater of: — head of water up to the top of the overflow — 1,8 m head of water above the highest point of tank (4) — setting pressure of the safety valves, where relevant
Deep tanks	Structural (1)	
Fuel oil tanks	Structural	
Scupper and discharge pipes in way of tanks	Structural (1)	
Sea inlet boxes Sonar domes	Structural (1)	— head of water up to the damage control deck/ vee line

Speed and depth instrument compartments	Structural (1)	— head of water up to the damage control deck/ vee line — top of the header tank
Double plate rudders	Structural (1), (5)	2,4 m head of water, and rudder should normally be tested while laid on its side
Double plate bilge keels	Structural (1)	— head of water up to the design waterline
Watertight bulkheads, shaft funnels, flats and recesses, etc.	Hose (2)	*See Vol 1, Pt 6, Ch 6, 6.6 Hose testing*
Watertight doors, hatches and closing appliances (below the vertical limit of watertight integrity) when fitted in place	Hose (6) and (7)	
Weathertight hatch covers, doors and closing appliances (above the vertical limit of watertight integrity)	Hose	
Fore peak not used as tank	Hose (2)	
Chain locker, if aft of collision bulkhead	Structural	Head of water up to the top of the overflow pipe
Independent/Separate fuel oil tanks Filing trunks	Structural	Head of water representing the maximum pressure which could be experienced in service for which elastic design criteria were used, but not less than 3,5 m
After peak not used as tank	Leak	*See Vol 1, Pt 6, Ch 6, 6.5 Leak testing*
Magazines	Leak (6) and (8)	*See Vol 1, Pt 6, Ch 6, 6.5 Leak testing*

Note 1. Leak or hydropneumatic testing may be accepted, provided that at least one tank of each type is structurally tested, to be selected in connection with the approval of the design, *see Vol 1, Pt 6, Ch 6, 6.7 Hydropneumatic testing*.

Note 2. When hose testing cannot be performed without damaging possible outfittings already installed, it may be replaced by a careful visual inspection of all the crossings and welded joints. Where necessary, dye penetrant test or ultrasonic leak test may be required.

Note 3. Where applicable testing of the after peak is to be carried out after the stern tube has been fitted.

Note 4. The highest point of the tank is generally to exclude hatchways.

Note 5. If leak or hydropneumatic testing is carried out, arrangements are to be made to ensure that no pressure in excess of 0,30 bar (0,30 kgf/cm^2) can be applied.

Note 6. Watertight doors and hatches to be supplied with a test certificate stating the maximum pressure head for which they are suitable. For large watertight closing appliances that cannot be tested, *see Vol 1, Pt 4, Ch 3, 3.4 Construction and testing* or *Vol 1, Pt 4, Ch 3, 4.3 Construction and testing*.

Note 7. *See also Regulation 16 - Construction and initial tests of watertight doors, sidescuttles, etc.*. Where the door has had the full hydrostatic test before installation, the hose test may be replaced by careful visual examination after full operational tests.

Note 8. If the magazine is required to contain an overpressure, for example due to a fire, the testing requirements are to be specified by the magazine safety standard.

6.2 Definitions

6.2.1 For the purpose of these procedures the following definitions apply:

(a) Protective coating is the coating system applied to protect the structure from corrosion. This excludes the prefabrication primer.

(b) Structural testing is a hydrostatic test carried out to demonstrate the tightness of the tanks and the structural adequacy of the design. Where practical limitations prevail and hydrostatic testing is not feasible, hydropneumatic testing (*see* (e)) may be carried out instead.

(c) Leak testing is an air or other medium test carried out to demonstrate the tightness of the structure.

(d) Hose testing is carried out to demonstrate the tightness of structural items not subjected to hydrostatic or leak testing, and other components which contribute to the watertight or weathertight integrity of the hull.

(e) Hydropneumatic testing is a combination of hydrostatic and air testing, consisting of filling the tank with water and applying an additional air pressure. The conditions are to simulate, as far as practicable, the actual loading of the tank and in no case is the air pressure to be less than given in *Vol 1, Pt 6, Ch 6, 6.5 Leak testing*

6.3 Testing arrangements

6.3.1 For tank and compartment penetrations not fitted with closing devices adjacent to the boundary, temporary closing devices are to be provided and stowed near to the penetration for periodic testing by ships' staff.

6.3.2 The testing of watertight doors, hatches and similar fittings are to be tested in such a manner as to force them off their seatings.

6.3.3 Bathrooms are to be tested with a flood to the level of the sill.

6.3.4 All Scupper soil and urinal pipes are to be tested to the maximum head experienced in service.

6.3.5 All piping systems are to be tested in accordance with *Vol 2, Pt 7, Ch 1, 16 Testing*

6.4 Structural testing

6.4.1 Generally all tanks or compartments that carry liquid in bulk are to be structurally tested at build.

6.4.2 Where it is intended to carry out structural tests after the protective coating has been applied welds are to be leak tested prior to the coating application.

6.4.3 For welds other than manual and automatic erection welds, manual fillet welds on tank boundaries and manual penetration welds, the leak test may be waived provided that careful visual inspection is carried out, to the satisfaction of the Surveyor, before the coating is applied. The cause of any discolouration or disturbance of the coating during the test is to be ascertained, and any deficiencies repaired.

6.4.4 Compartments to be tested are to be structurally complete and all fittings which affect the watertight integrity of the compartment such as doors, hatches, manholes, penetrations, valves and glands are to be fitted.

6.4.5 In compartments containing the stabiliser fins, rudder stocks, sonar hull outfit, echo sounders, etc. the bearing houses are to be installed and the seating arrangements completed before testing.

6.4.6 Arrangements are to be provided to ensure the free passage of air from the top of the tank tested. The air pipe or indicator test plug may be used for this purpose.

6.4.7 Where necessary, additional temporary supports are to be fitted to the hull to prevent excessive deformation.

6.4.8 Structural testing may be carried out afloat where testing using water is undesirable in dry dock or on the building berth. The testing afloat is to be carried out by separately filling each tank and cofferdam to the test head given in *Table 6.6.1 Testing requirements* An internal inspection of the tanks is to be made whilst the ship is afloat.

6.4.9 Where permitted by *Table 6.6.1 Testing requirements*, complete structural testing may be replaced by a combination of leak and structural testing, as follows: The leak test is generally to be carried out on each tank while the craft is in dry dock or on the building berth:

(a) Double bottom tanks and cofferdams may be leak tested on the berth, and structural tests carried out afloat.

(b) All deep tanks are to be structurally tested.

(c) Interconnecting deep and double bottom tanks and ‘flume’ type stabilisation tanks are to be structurally tested to the test head given in *Table 6.6.1 Testing requirements*

6.4.10 Equivalent proposals for testing will be considered.

6.4.11 It is recommended that a leak test in accordance with *Vol 1, Pt 6, Ch 6, 5.7 Watertight collars* is carried out before the structural test commences to identify any leak paths which may compromise the structural test.

6.5 Leak testing

6.5.1 Generally all boundaries for watertight subdivision are to be given a leak test when structural work is complete. The test is to be carried out before the compartment is fitted out and linings or covering applied.

6.5.2 Testing is to be carried out by applying an efficient indicating liquid, e.g. soapy water solution, to the weld or outfitting penetration being tested, while the tank or compartment is subject to an air pressure of at least 0,15 bar (0,15 kgf/cm^2).

6.5.3 It is recommended that the air pressure be raised to 0,2 bar (0,2 kgf/cm^2) and kept at this level for about one hour to reach a stabilised state, with a minimum number of personnel in the vicinity, and then lowered to the test pressure prior to inspection.

6.5.4 A U-tube filled with water to a height corresponding to the test pressure is to be fitted for verification and to avoid over-pressure. The U-tube is to have a cross-section larger than that of the air supply pipe. In addition, the test pressure is to be verified by means of a calibrated pressure gauge, or alternative equivalent system.

6.5.5 Leak testing is to be carried out, prior to the application of a protective coating, on all fillet welds and erection welds on tank boundaries, except welds made by automatic processes and on all outfitting penetrations.

6.5.6 Selected locations of automatic erection welds and pre-erection manual or automatic welds may also be required to be tested before coating, at the discretion of the Surveyor.

6.6 Hose testing

6.6.1 Hose testing is to be carried out on all structure that is required to be weathertight and has not been tested by structural or air testing.

6.6.2 Testing is to be carried out at a maximum distance of 1,5 m with a hose pressure not less than 2,0 bar (2,0 kgf /cm^2). The nozzle diameter is not to be less than 12 mm. The jet is to be targeted directly onto the weld or seal being tested.

6.6.3 The duration of hose testing is to be at the discretion of the surveyor. Leaks are to be marked, repaired and retested until no water leakage is detected.

6.7 Hydropneumatic testing

6.7.1 When this is performed, the safety precautions identified in *Vol 1, Pt 6, Ch 6, 6.5 Leak testing* are to be followed.

6.8 Gastight testing

6.8.1 Where LR has been requested to witness gastight testing in accordance with a specified standard, the boundaries of citadels and zones defined in *Vol 1, Pt 4, Ch 1, 7 Design guidance for nuclear, biological and chemical defence* are to be tested for gas tightness using a pressure drop test. In addition, compartments containing noxious or explosive gases such as Acetone, Dope, Flammable stores, Oxygen, etc. are to be subject to a pressure drop test.

6.8.2 The test is to be carried out with compartment as near to completion as possible. Further work on a compartment after the test may result in a retest.

6.8.3 The pressure in the compartment is to be brought to 0,015 Bar (0,015 kgf/cm^2) (150 mm of fresh water) and the supply isolated. The fall in pressure after 10 minutes is not to be greater than 0.0013 Bar (0,0013 kgf/cm^2) (13 mm of fresh water).

6.8.4 A U-tube filled with water to a height corresponding to the test pressure is to be fitted for verification and to avoid overpressure. The U-tube is to have a cross-section larger than that of the air supply pipe.

6.8.5 If the pressure drop specified in *Vol 1, Pt 6, Ch 6, 6.8 Gastight testing 6.8.3* occurs, the compartment is to be inspected for leaks and the test repeated until the specified standard is achieved.

6.8.6 In certain compartments that are not able to be made fully gastight due to operational requirements, a greater fall in pressure may be accepted at the discretion of the surveyor. In no case is the pressure to drop more than 0,0075 Bar (0,0075 kgf/cm^2) (75 mm of fresh water) in 10 minutes from an initial 0,015 Bar (0,015 kgf/cm^2) (150 mm of fresh water).

6.8.7 Consideration will be given to the testing of adjacent boundaries or equivalent in those spaces which are not able to be closed, such as gun rings and main machinery spaces.

■ *Section 1* General

1.1 Application

1.1.1 This Part gives the procedures that may be optionally applied for the structural design and assessment of all naval ships. Ships which comply with these requirements will be eligible to be assigned the additional class notations applicable to each procedure. The full list of class notations is given in *Vol 1, Pt 1, Ch 2 Classification Regulations*.

1.1.2 The requirements for the following additional class notations are included within this Part:

TLA Total Load Assessment.

SDA Structural Design Assessment.

■ *Section 2* Total Load Assessment, TLA

2.1 Total Load Assessment notation – TLA

2.1.1 The **TLA** procedure is an optional procedure and is applied on a voluntary basis.

2.1.2 The ship's structure is examined using a total load approach and stress analysis techniques.

2.1.3 The total load approach applies static, hydrodynamic and inertial load components to the structure making due allowance for the local structural configuration. These load components include global and local considerations. The approach includes load combination factors which enable the total design loads to take account of the appropriate phase relationships between the various load parameters, e.g. relative vertical motion and global bending moment.

2.1.4 The stress analysis techniques predict the total stresses acting in the structure as a consequence of the total loads. These techniques cover the assessment of stresses in either primary/secondary plating systems or grillage systems.

2.1.5 The resulting stresses are then checked against a set of design factors, which include stress, deflection and buckling requirements.

2.1.6 Due to the nature of the **TLA** approach it is possible to achieve the following:

(a) Allow the designer to examine different loading scenarios
(b) Optimise the structure towards particular design solutions.

2.1.7 The **TLA** procedure is in addition to the normal Rule structural design approval requirements specified within *Vol 1, Pt 6, Ch 3 Scantling Determination*

2.1.8 The requirements for the **TLA** method are given in *Vol 1, Pt 7, Ch 2 Total Design Loads* and *Vol 1, Pt 7, Ch 3 Total Load Assessment, TLA*. Chapter 2 contains the requirements for the total design loads to be applied to the structure and Chapter 3 contains the requirements for the stress analysis and verification to be performed using these loads.

Section 3
Structural Design Assessment, SDA

3.1 Structural Design Assessment notation – SDA

3.1.1 The **SDA** procedure is an optional procedure and is applied on a voluntary basis when an Owner or designer seeks to increase confidence levels in the structural integrity of a ship.

3.1.2 The ship structure is to be examined using finite plate element methods to assess both the overall and detailed structural capability to withstand static and dynamic loadings.

3.1.3 The **SDA** procedure is in addition to the normal Rule structural design approval requirements specified within *Vol 1, Pt 6, Ch 3 Scantling Determination*.

3.1.4 The **SDA** procedure may be mandatory for very structurally complex ships. For complex ships, the ship designer is to supply outline details of the ship to LR at an early stage in the design in order that agreement can be reached on the appropriate level of analysis required.

3.1.5 Where applicable, the ship structure is to be examined for the structural capability to withstand dynamic loadings from partially filled tanks or the influence of thermal loadings.

■ *Section 1* General

1.1 Application

1.1.1 This Chapter specifies the method by which the total design loads for the optional Total Load Assessment, **TLA**, approach are derived. The **TLA** approach is given in *Vol 1, Pt 7, Ch 3 Total Load Assessment, TLA*, an overview of the **TLA** approach is given in *Vol 1, Pt 7, Ch 3, 1 Introduction* and illustrated in *Figure 3.1.1 Overview of the Total Load Assessment, TLA Procedure*

1.1.2 The total design loads derived in this Chapter are also to be used to form the basic load cases for the optional Structural Design Assessment, **SDA**, procedure, *see Vol 1, Pt 7, Ch 1, 3.1 Structural Design Assessment notation – SDA*.

1.1.3 The total design loads are derived by combining the local and global design loads, defined in *Vol 1, Pt 5, Ch 3 Local Design Loads* and *Vol 1, Pt 5, Ch 4 Global Design Loads* respectively, using load combination factors. These loads represent typical maximum values of combined loads that are simultaneously applied to the structure of a ship.

1.1.4 The total design loads given in this Chapter are applicable to all naval ships which are operating in the displacement mode.

1.1.5 The total design loads for ships that are operating in the planing or non-displacement modes will need to be specially considered. The loads given here are applicable for these ships whilst they are operating in the displacement mode, i.e. in severe sea states when planing is not possible.

1.2 Overview of total design loads

1.2.1 The total design loads to be applied to each structural item are to include the following load and pressure components where applicable:

- global hull girder stress due to vertical bending, σ_{hg} in N/mm^2, derived in accordance with *Vol 1, Pt 6, Ch 4 Hull Girder Strength*;
- global hull girder shear stress loads, τ_{hg} in N/mm^2, derived in accordance with *Vol 1, Pt 6, Ch 4 Hull Girder Strength*;
- local pressure loads, P in kN/m^2, where P is the appropriate design pressure value for each component;
- local transverse, LT, or vertical support, LV, loads, in kN;
- mass inertial forces, in kN;
- local shear force loads, in kN.

1.2.2 In addition to the above loads, it may be necessary to consider the effects of the following on the structural components:

- bending of primary structure supported by major bulkheads;
- bending of primary structure supported by the side shell or longitudinal bulkheads;
- lateral bending moments and shear forces;
- global and local torsional moments.

1.2.3 Most of the above load components include a dynamically fluctuating component due to ship motions, e.g. side shell pressure due to wave and ship motion. These loads will not all be maximum simultaneously, due to their cyclic nature and the

phase relationship between load values. Consequently it is not necessary to apply the maximum values of all these load components to the structure at the same time. *Vol 1, Pt 7, Ch 2, 3 Design load combinations* gives a method of combining these loads in order that representative total design loads may be applied to the structure.

1.2.4 The method of deriving the Total Design Loads for each structural component is given in *Vol 1, Pt 7, Ch 2, 4 Design load systems for longitudinally effective components* and *Vol 1, Pt 7, Ch 2, 5 Design load systems for structural components or longitudinally ineffective material*. However, it remains the responsibility of the designer to ensure that the loads applied are representative.

1.2.5 Details of all the loads applied to each structural component are to be supplied to Lloyd's Register (hereinafter referred to as 'LR').

1.2.6 The major load components to be applied to, or reacted by, the structure are illustrated in *Figure 2.1.1 Loads and stresses to be applied to the structure*

1.3 Environmental conditions

1.3.1 The environmental conditions for the determination of the total design loads are to be based on the normal environmental design criteria specified in *Vol 1, Pt 5, Ch 2, 2.3 Wave environment* unless otherwise stated.

1.3.2 The standard values of wave height factor, f_{Hs}, and service area factor, f_s, given in *Vol 1, Pt 5, Ch 3, 1.2 Environmental conditions 1.2.2* and *Vol 1, Pt 5, Ch 2, 2.4 Service Area factors* respectively are to be used for the total design loads unless otherwise stated. These factors may be adjusted for damaged loading conditions, residual strength analysis, **RSA**, or for special operating conditions, e.g. a deep draft condition for the recovery of amphibious vehicles in sheltered waters.

1.4 Direct calculations

1.4.1 Alternative methods of establishing the total design loads will be specially considered, provided that they are based on established codes or standards acceptable to LR. In such cases, full details of the methods used are to be provided when plans are submitted for approval.

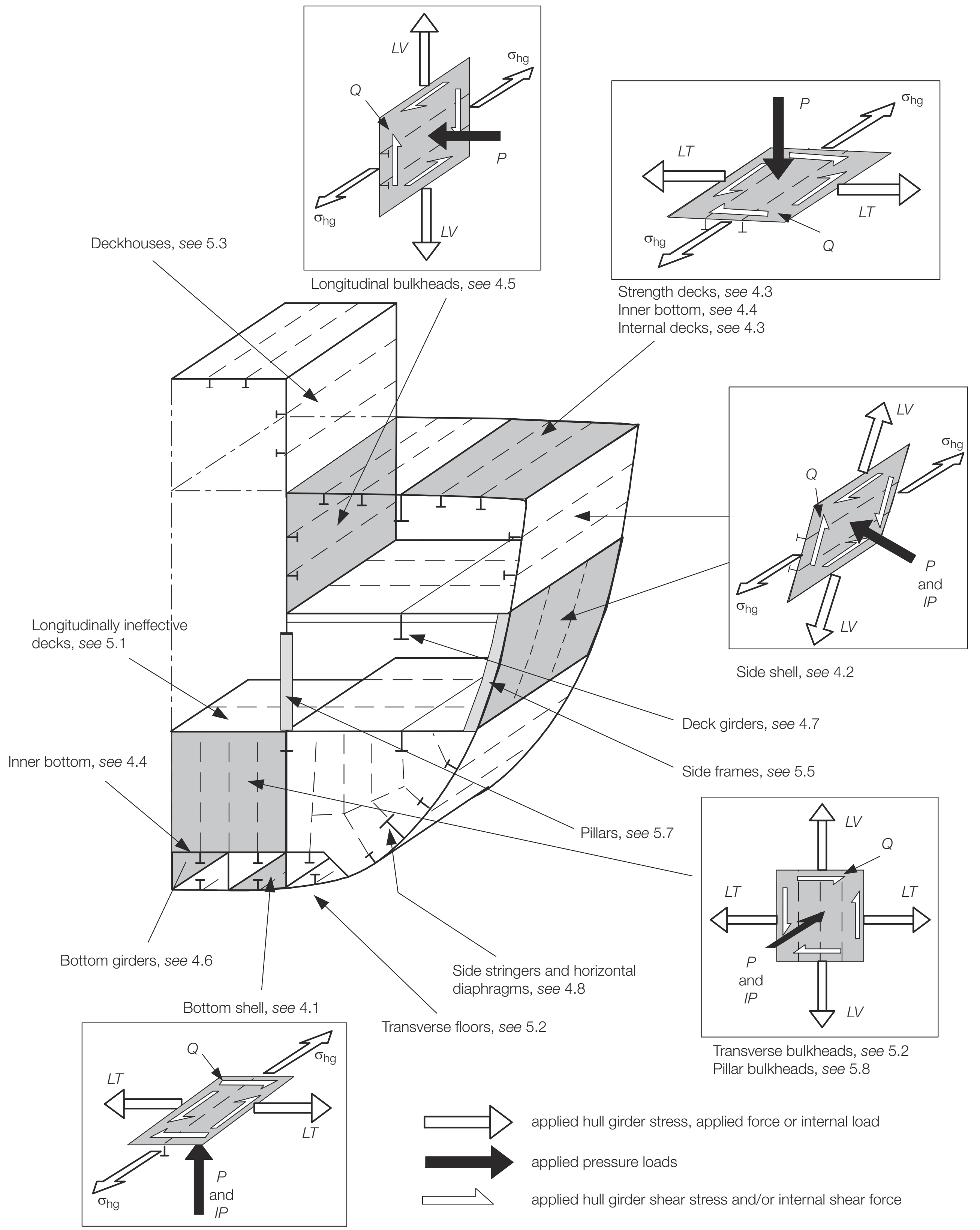


Figure 2.1.1 Loads and stresses to be applied to the structure

1.4.2 Throughout this Chapter, recommended values of effectiveness, ε, are given for each structural component. These effectiveness values specify the proportion of a particular load carried by a structural component as opposed to other supporting structure, *see* the text for more details. These efficiency values may be derived by direct calculation, similar ship analysis or other suitable techniques. The methods used and values derived are to be agreed with LR.

■ *Section 2* Nomenclature and design factors

2.1 Nomenclature

2.1.1 The nomenclature used in this Chapter to describe the loads applied to or reacted by the structure and local dimensional characteristics, e.g. breadths and spans, is based on the following format:

(a) A_{Suffix}

where

The letter *A* is the load type or dimension letter and is one of the following:

Load types

P = denotes an applied normal pressure load, i.e. normal to the plate.

I P = denotes an applied impulse or impact pressure load.

F = denotes an applied point load due to gravity and mass inertial effects.

LV = denotes an internally generated load acting in the predominantly vertical direction as a consequence of applied forces and pressures, e.g. pillar bulkhead compressive loads.

LT = denotes an internally generated load acting in the predominantly transverse direction as a consequence of applied forces and pressures, e.g. transverse deck compressive loads.

QV = denotes a shear force due to local load considerations acting in the predominantly vertical direction.

QT = denotes a shear force due to local load considerations acting in the predominantly transverse direction.

σ = denotes a direct stress to apply as a consequence of hull girder bending.

τ = denotes a direct shear stress to apply as a consequence of hull girder shear forces.

Dimensions

B = breadth, in metres, of an area of supported plate or dimension of a structural member. *B* is always measured in the transverse direction.

S = length of an area of supported plating or dimension of a structural member. *S* is always measured in the longitudinal direction.

H = height of an area of supported plating or dimension of a structural member. *H* is always measured in the vertical direction.

Suffix is either of the following:

Lower case = to denote a local load value which was derived in accordance with *Vol 1, Pt 5, Ch 3 Local Design Loads*

Upper case = to denote a resultant load value that is applied to the structural item under consideration.

2.1.2 The symbols used in this Chapter for loads are given below:

Local load or pressure components

P_{h} = shell envelope hydrostatic pressure, *see Vol 1, Pt 5, Ch 3, 3.2 Combined hydrostatic and hydrodynamic pressure on the shell plating, Ps*

P_{w} = shell envelope hydrodynamic pressure, *see Vol 1, Pt 5, Ch 3, 3.3 Hydrostatic pressure on the shell plating, Ph*

P_{wd} = pressure on weather deck, *see Vol 1, Pt 5, Ch 3, 3.5 Pressure on exposed and weather decks, Pwd*

$I\,P_{bi}$ = bottom impact pressure, *see Vol 1, Pt 5, Ch 3, 4.2 Bottom impact pressure, IPbi*

$I\,P_{bf}$ = Bow flare or above waterline impact pressure, *see Vol 1, Pt 5, Ch 3, 4.3 Bow flare and wave impact pressures, IPbf*

P_{in} = pressure on internal deck, *see Vol 1, Pt 5, Ch 3, 5.3 Pressure on internal decks, Pin*

P_{cd} = pressure on cargo deck, *see Vol 1, Pt 5, Ch 3, 5.4 Loads for decks designed for cargo or heavy equipment loads, Pcd and Wcd*

P_{ra} = pressure on ramps or lifts, *see Vol 1, Pt 5, Ch 3, 6.2 Loads for ramps and lifts, Pra*

H_{tk} = pressure height for tank bulkheads, *see Vol 1, Pt 5, Ch 3, 5.6 Pressure height for deep tank bulkheads and boundaries, Htk*

H_{da} = pressure height for watertight bulkheads, *see Vol 1, Pt 5, Ch 3, 5.7 Pressure height for watertight bulkheads and boundaries, Hda*

Design loads and pressures for structural components

P_{BS} = design pressure for bottom structure.

P_{SS} = design pressure for side shell structure.

P_{DK} = design pressure for deck structure.

P_{WD} = design pressure for weather deck.

P_{ID} = design pressure for interior deck.

P_{IB} = design pressure for inner bottom.

P_{LB} = design pressure for longitudinal bulkheads.

P_{FL} = design pressure for bottom floors and transverses.

P_{DH} = design pressure for deckhouse, bulwarks and superstructures plating.

P_{DT} = design pressure for deep tank bulkheads.

P_{WT} = design pressure for watertight bulkheads.

L_{PI} = design load carried by pillars.

L_{PB} = design load carried by pillar bulkheads.

P_{CD} = design pressure to be applied to cargo decks.

F_{CD} = design load due to discreet mass items to be applied to decks.

P_{IMP} = design pressure for decks subject to impulsive loads.

P_{WI} = design pressure for deckhouse and superstructure windows.

QT_{DK} = local shear force for deck plating.

QT_{FL} = local shear force for floors.

QV_{BG} = local shear force for bottom girders.

NOTE

[F] = denotes a force matrix, i.e. a group of forces which are applicable to the structural item under consideration.

2.1.3 Other symbols and definitions applicable to this Chapter are defined below or in the appropriate sub-Section:

(a) T and L_R are defined in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars*

2.1.4 The units for pressures are in kN/m^2 and the units for loads and forces are in kN. Stresses are in N/mm^2. Positive loads and stresses are tensile, negative are compressive.

2.1.5 The design pressure, p, used in scantling formulae in *Vol 1, Pt 7, Ch 3, 2 Structural resistance* is to be taken as the appropriate pressure value defined in this Chapter.

2.1.6 For a direct calculation using finite element (FE) analysis, only loads and pressures with a load type letter of P, IP or F are normally to be applied to the FE structural model. Load type letters σ_{hg} and τ_{hg} may need to be applied as global bending moments and shear forces, i.e. M_D and Q_D, depending on the extent of the FE structural model.

■ *Section 3* Design load combinations

3.1 General

3.1.1 The local and global loads given in *Vol 1, Pt 5, Ch 3 Local Design Loads* and *Vol 1, Pt 5, Ch 4 Global Design Loads* do not include any allowance for phase relationships between the various loadings. These loads are not all maximum at the same time and consequently it is not correct to apply all loads simultaneously to the structure. The purpose of this section is to define the phase relationships and hence allow typical maximum load combinations to be applied to the structure.

3.1.2 Special load case combinations may be required to reflect specific operational requirements of the vessel, e.g. sea state 6 operation with the stern well dock flooded for amphibious operations. The details of such operational modes together with any service limitations are to be recorded in the design disclosure document and the Operations Manual, Loading Manual or Stability Information Book.

3.1.3 Proposals for deriving the load combinations using direct calculation techniques are to be agreed with LR at the earliest opportunity.

3.2 Design cases for load combinations

3.2.1 The load combinations given in *Table 2.3.1 Design load combination factors* are the minimum to be considered for the assessment of the scantlings. Additional load combination cases may be required to demonstrate that the structure is adequate.

3.2.2 Each set of load combinations may need to be considered for individual loading conditions to account for differences in local loadings, e.g. different tank fillings, payload or other loadings. This may be performed either using:

(a) an envelope approach with due consideration of full/ empty tanks, etc. or

(b) as individual load combination sets, in which case the actual still water bending moment and shear force distributions may be used together with the actual draft, trim and deadweight distribution.

For example, it will be necessary to consider two design cases to review the double bottom tanks, i.e. one with the double bottom tank full and one with the double bottom tank empty.

3.2.3 Load combination cases 1 to 4 are based on the premise that the maximum wave bending moment and shear forces are likely to be generated on a wave that has the same length as the ship.

Table 2.3.1 Design load combination factors

Case No	1	2	3	4	5	6
Design factor	Design Sag case Crest at FP Trough at 0,5L_R	Max pitch bow up Crest at 0,75L_R Trough at 0,25L_R	Design Hog case Crest at 0,5L_R Trough at FP	Max pitch bow down Crest at 0,25L_R Trough at 0,75L_R	Roll case	Design factor affects the following loads
w_g (global loads)	–1,0	$\frac{+\sin(\pi x/L_R)}{2}$	+1,0	$\frac{+\sin(\pi x/L_R)}{2}$	To be specially considered	M_W, M_{WRS}, Q_W and Q_{WRS} *see Vol 1, Pt 7, Ch 2, 3.3 Design global loads – Intact conditions* and *Vol 1, Pt 7, Ch 2, 3.4 Design global loads – Damaged conditions or Residual Strength Assessment (RSA) conditions*
w_p (external pressure loads)	+ cos (2πx/L_R)	–sin (2πx/L_R)	+ cos (2πx/L_R)	–sin (2πx/L_R)	To be specially considered	P_{SS}, *Vol 1, Pt 7, Ch 2, 3.6 External shell pressures* LT QT
w_f (inertial loads)	Combined heave and pitch design factor based on w_{fheave} and w_{fpitch}, *see Vol 1, Pt 7, Ch 2, 3.5 Inertial force load combination factor, wf*					P_{CD}, F_{CD} LV, L_A
w_{fheave} (heave inertial)	+1	0	–1	0	To be specially considered	
w_{fpitch} (pitch inertial)	0	+1	0	–1	To be specially considered	

Note 1. The factor w_g is to be applied to the dynamic portion of the load, *see Vol 1, Pt 7, Ch 2, 3.3 Design global loads – Intact conditions* and *Vol 1, Pt 7, Ch 2, 3.4 Design global loads – Damaged conditions or Residual Strength Assessment (RSA) conditions*.

Note 2. The factor w_p is to be applied to the dynamic portion of the load component, *see Vol 1, Pt 7, Ch 2, 3.6 External shell pressures*.

Note 3. The factor w_f is to be applied to the dynamic portion of the load component, *see Vol 1, Pt 7, Ch 2, 3.5 Inertial force load combination factor, wf*. The w_{fheave} and w_{fpitch} factors are required to consider the phasing between heave and pitch accelerations.

Note 4. x is the longitudinal location under consideration.

Note 5. Sin and cos are the sine and cosine functions with the angle in radians.

3.2.4 Each load case combination consists of a set of w factors, some of these combination factors are longitudinally position dependent factors, e.g. the w_p term will produce maximum pressure amidships and low pressures at the ends for the maximum hogging BM case.

3.3 Design global loads – Intact conditions

3.3.1 The design global hull girder vertical bending moment to be associated with the design load combination cases is as follows:

$$M_D = M_S + |w_g| M_W \text{ kNm}$$

where

$|w_g|$ = absolute value of w_g

M_S and M_W are the sagging or hogging values of M_S and M_W at the longitudinal position under consideration. If w_g is positive then the hogging values of M_S and M_W are to be taken, otherwise w_g is negative and the sagging values of M_S and M_W are to be taken.

M_S and M_W are given in *Vol 1, Pt 5, Ch 4, 2.2 Still water bending moments* and *Vol 1, Pt 7, Ch 2, 3.3 Design global loads – Intact conditions*

w_g is given in *Table 2.3.1 Design load combination factors*.

3.3.2 The design global hull girder vertical shear force to be associated with the design load combination cases is as follows:

$$Q_D = Q_S + |w_g| Q_W \text{ kN}$$

where

$|w_g|$ = absolute value of w_g

Q_S and Q_W are the sagging or hogging values of Q_S and Q_W at the longitudinal position under consideration. If w_g is positive then the hogging values of Q_S and Q_{WH} are to be taken, otherwise w_g is negative and the sagging values of Q_S and Q_{WS} are to be taken.

Q_S is given in *Vol 1, Pt 5, Ch 4, 2.3 Still water shear forces*

Q_{WS} and Q_{WH} are given in *Vol 1, Pt 7, Ch 2, 3.7 Vertical wave shear forces*

w_g is given in *Table 2.3.1 Design load combination factors*

3.4 Design global loads – Damaged conditions or Residual Strength Assessment (RSA) conditions

3.4.1 The design global hull girder vertical bending moments to be associated with the design load combination cases for residual strength assessment or damaged conditions is to be taken as follows:

$$M_D = M_{SRS} + |w_g| M_{WRS} \text{ kNm}$$

where.

$|w_g|$ = absolute value of w_g

M_{SRS} and M_{WRS} are the sagging or hogging values of M_{SRS} and M_{WRS} at the longitudinal position under consideration. If w_g is positive then the hogging values of M_{SRS} and M_{WRS} are to be taken, otherwise w_g is negative and the sagging values of M_{SRS} and M_{WRS} are to be taken.

M_{SRS} and M_{WRS} are given in *Vol 1, Pt 5, Ch 4, 5.6 Damaged still water shear forces and bending moments*

w_g is given in *Table 2.3.1 Design load combination factors*

3.4.2 The design global hull girder vertical shear force to be associated with the design load combination cases for residual strength assessment or damaged conditions is to be taken as follows:

$$Q_D = Q_{SRS} + |w_g| Q_{WRS} \text{ kN}$$

where

$|w_g|$ = absolute value of w_g

Q_{SRS} and Q_{WRS} are the sagging or hogging values of Q_{SRS} and Q_{WRS} at the longitudinal position under consideration. If w_g is positive then the hogging values of Q_{SRS} and $Q_{WRS,H}$ are to be taken, otherwise w_g is negative and the sagging values of Q_{SRS} and $Q_{WRS,S}$ are to be taken.

Q_{SRS} is given in *Vol 1, Pt 5, Ch 4, 5.6 Damaged still water shear forces and bending moments* and *Vol 1, Pt 5, Ch 4, 5.4 Residual strength vertical wave shear forces*

w_g is given in *Table 2.3.1 Design load combination factors*

$Q_{WRS,S}$ and $Q_{WRS,H}$ are given in *Vol 1, Pt 7, Ch 2, 3.7 Vertical wave shear forces 3.7.2*

3.5 Inertial force load combination factor, w_f

3.5.1 The inertial force load combination factor, w_f, to be associated with the design load combination cases is as follows:

$$w_f = (1 + a_z)$$

where

$$a_z = w_{fheave} a_{heave} + w_{fpitch} a_{pitch}$$

w_{fheave} and w_{fpitch} are to be taken for the appropriate loading condition, *see Table 2.3.1 Design load combination factors*

a_{heave} and a_{pitch} are defined in *Table 3.2.1 Ship motions*

3.6 External shell pressures

3.6.1 The side shell pressure, P_{SS}, to be applied to all external plating is to be derived as follows:

$$P_{SS} = P_h + w_p P_w \text{ kN/m}^2$$

but

$$P_{SS} \geq 0$$

w_p is defined in *Table 2.3.1 Design load combination factors*

P_h and P_w are defined in *Vol 1, Pt 5, Ch 3, 3.2 Combined hydrostatic and hydrodynamic pressure on the shell plating, Ps* and *Vol 1, Pt 5, Ch 3, 3.3 Hydrostatic pressure on the shell plating, Ph*.

3.6.2 The weather deck pressure, P_{WD}, to be applied to all external plating is to be derived as follows:

$$P_{WD} = P_h + w_p P_{wd} \text{ kN/m}^2$$

but

$P_{WD} \geq 0$

w_p is defined in *Table 2.3.1 Design load combination factors*

P_{wd} is defined in *Vol 1, Pt 5, Ch 3, 3.5 Pressure on exposed and weather decks, Pwd*

3.7 Vertical wave shear forces

3.7.1 The wave shear force curves associated with the hogging and sagging bending moments required by the total load approach are to be taken as follows:

Q_{WH} = shear force distribution to give the hogging bending moment

$= 3K_b M_o/L_R$ kN

where

K_b is to be taken as follows:

K_b = 0 at aft end of L_R

$= +0{,}836F_{fH}$ between $0{,}2L_R$ and $0{,}3L_R$

$= +0{,}65F_{fH}$ between $0{,}4L_R$ and $0{,}5L_R$

$= -0{,}65F_{fH}$ between $0{,}5L_R$ and $0{,}6L_R$

$= -0{,}91F_{fH}$ between $0{,}7L_R$ and $0{,}85L_R$

$= 0$ at forward end of L_R

Q_{WS} = shear force distribution to give the sagging bending moment

= $3K_b M_o/L_R$ kN

where

K_b is to be taken as follows:

K_b = 0 at aft end of LR

= $+0{,}836F_{fS}$ between $0{,}15L_R$ and $0{,}3L_R$

= $+0{,}65F_{fS}$ between $0{,}4L_R$ and $0{,}5L_R$

= $+0{,}65F_{fS}$ between $0{,}5L_R$ and 0,6LR

= $-0{,}91F_{fS}$ between $0{,}7L_R$ and $0{,}85L_R$

= 0 at forward end of L_R

Intermediate values are to be determined by linear interpolation.

M_o, F_{fH} and F_{fS} are given in *Vol 1, Pt 5, Ch 4, 3.3 Vertical wave bending moments*

3.7.2 The wave shear force associated with the residual strength assessment load cases or damaged load cases is to be taken as follows:

$Q_{WRS,H}$ = shear force distribution to give the hogging bending moment

= $K_{fRS} Q_{WH}$

where

Q_{WH} = is taken as in *Vol 1, Pt 7, Ch 2, 3.7 Vertical wave shear forces 3.7.1*

K_{fRS} = is given in *Vol 1, Pt 5, Ch 4, 5.2 Environmental conditions*

$Q_{WRS,S}$ = shear force distribution to give the sagging bending moment

= $K_{fRS} Q_{WS}$

where

Q_{WS} = is taken as in *Vol 1, Pt 7, Ch 2, 3.7 Vertical wave shear forces 3.7.1*

■ *Section 4*
Design load systems for longitudinally effective components

4.1 Bottom shell structures (BS)

4.1.1 The design load values calculated here are to be used to determine the scantlings of bottom shell plating and stiffeners between the keel and the turn of bilge, *see Figure 2.4.1 Loads to be applied to bottom shell structure*

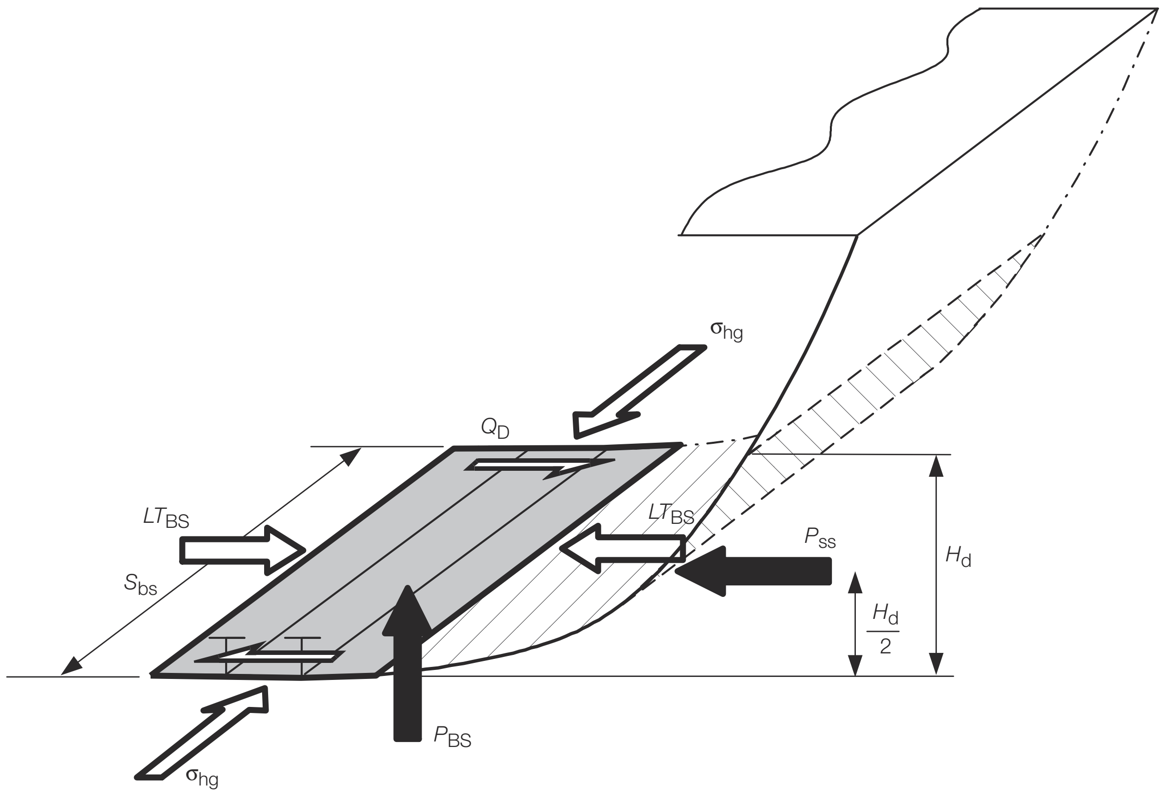


Figure 2.4.1 Loads to be applied to bottom shell structure

4.1.2 The design normal pressure, P_{BS}, for the bottom shell plating and stiffeners is to be taken as:

$$P_{BS} = P_{SS} \text{ kN/m}^2$$

where

P_{SS} = is defined in *Vol 1, Pt 7, Ch 2, 3.6 External shell pressures 3.6.1*

4.1.3 The design impulse pressure, $I\,P_{BS}$, for the bottom shell plating and stiffeners is to be taken as

$I\,P_{bi}$ = kN/m^2 (bottom impact)

where

$I\,P_{bi}$ = is defined in *Vol 1, Pt 7, Ch 2, 2.1 Nomenclature 2.1.2*

4.1.4 The design global vertical bending moment for bottom shell plating and longitudinals is to be taken as M_D, as defined in *Vol 1, Pt 7, Ch 2, 3.3 Design global loads – Intact conditions* or *Vol 1, Pt 7, Ch 2, 3.4 Design global loads – Damaged conditions or Residual Strength Assessment (RSA) conditions*

4.1.5 The design transverse load, LT_{BS}, due to hydrostatic and hydrodynamic compressive loading is to be taken as follows:

$$LT_{BS} = -\varepsilon_{BS} P_{SS} H_d S_{bs} \text{ kN}$$

where

H_d = half the vertical distance from the keel to the first effective full breadth deck above the inner bottom, or above the keel, in m. If no effective full breadth decks exist, then H_d is to be taken to the strength deck. H_d is illustrated in *Figure 2.4.2 Design parameter Hd for transverse load*

S_{bs} = length of the bottom shell plating between major transverse bulkheads, in metres

ε_{BS} = effectiveness of the bottom shell plating, i.e. the relative proportion of the load carried by the bottom shell as opposed to other structure such as the inner bottom, floors and bulkheads

= 0,5 for full breadth double bottom structures

= 1,0 for single bottom structures or partial breadth double bottom structures

P_{SS} is to be taken at a height $H_d/2$ above the keel. P_{SS} is defined in *Vol 1, Pt 7, Ch 2, 3.6 External shell pressures 3.6.1*

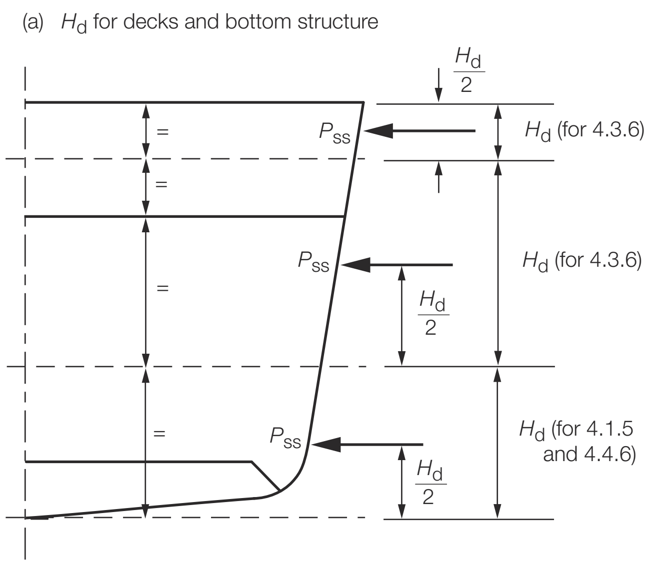
4.1.6 The design global shear force, Q_D, may be ignored for the bottom plating.

4.1.7 The design loads for bottom structure primary members are given in *Vol 1, Pt 7, Ch 2, 4.6 Bottom longitudinal girders (BG)*, bottom longitudinal girders, and *Vol 1, Pt 7, Ch 2, 5.4 Transverse floors (FL)*, transverse floors.

4.2 Side shell structures (SS)

4.2.1 The design pressures calculated here are to be used to determine the scantlings of side shell plating and stiffeners from the turn of bilge up to the weather deck, *see Figure 2.4.3 Loads to be applied to side shell structure*

4.2.2 For the side shell structure the design normal pressure, P_{SS}, is to be taken as defined in *Vol 1, Pt 7, Ch 2, 3.6 External shell pressures 3.6.1*



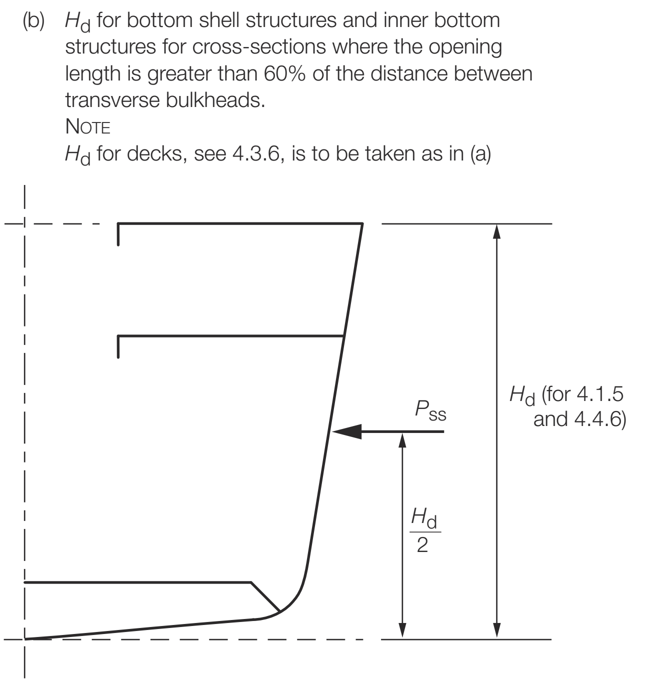


Figure 2.4.2 Design parameter H_d for transverse load

4.2.3 The design impulse pressure, IP_{SS}, for the side shell plating and stiffeners is to be taken as follows:

(a) up to the design waterline

$IP_{SS} = IP_{bi}$ kN/m^2 (bottom impact)

(b) above the design waterline

$IP_{SS} = IP_{bf}$ kN/m^2 (bow flare impact)

where

IP_{bi} and IP_{bf} are defined in *Vol 1, Pt 7, Ch 2, 2.1 Nomenclature 2.1.2*

4.2.4 The design global vertical bending moment is to be taken as M_D, as defined in *Vol 1, Pt 7, Ch 2, 3.3 Design global loads – Intact conditions* or *Vol 1, Pt 7, Ch 2, 3.4 Design global loads – Damaged conditions or Residual Strength Assessment (RSA) conditions*

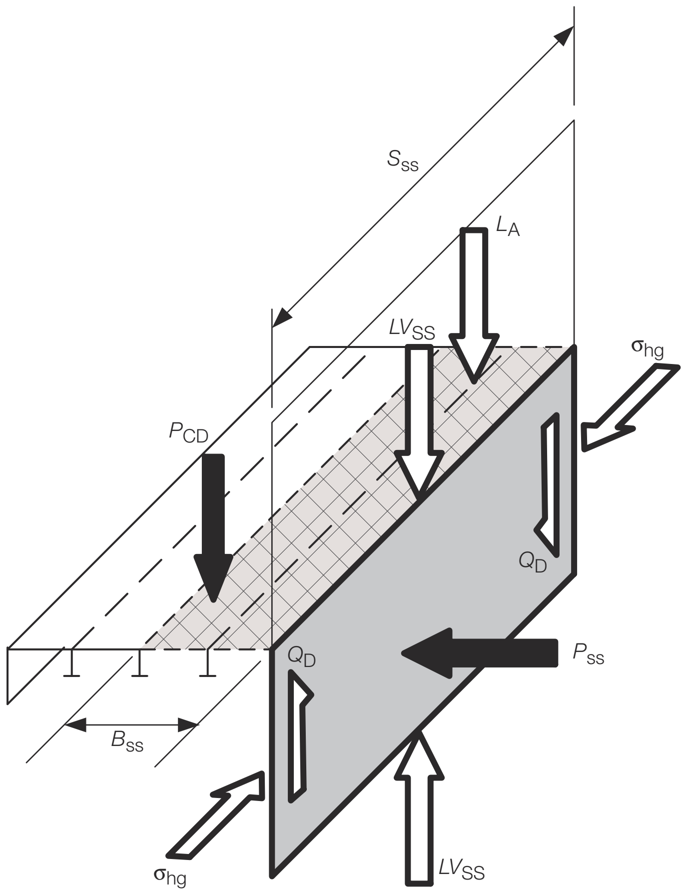


Figure 2.4.3 Loads to be applied to side shell structure

4.2.5 The design vertical load, LV_{SS}, supported by the side shell plating and stiffeners is to be taken as:

$$LV_{SS} = -\varepsilon_{SS} (S_{ss} B_{ss} P_{CD} + L_A + [F_{CD}]) \text{ kN}$$

where

ε_{SS} = effectiveness of the side shell plating, i.e. the relative proportion of the load carried by the side shell as opposed to the bounding major transverse bulkheads

= 0,5

P_{CD} = basic inertial deck design pressure, as appropriate, plus any other local loadings directly above the side shell, in kN/m^2, *see Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.2*

$[F_{CD}]$ = inertial load or loads, in kN, from items of equipment, etc. on the supported deck, assumed zero if there is none over. F_{CD} is defined in *Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.5*

L_A = appropriate load, in kN, from pillar(s), bulkheads and side shell structure above the supported deck, assumed zero if there is none over. L_A may be taken as LV_{BP} for the supported bulkhead. LV_{PB} is given in *Vol 1, Pt 7, Ch 2, 5.8 Pillar bulkheads (PB)*

$S_{ss}\, B_{ss}$ = are the effective deck area supported by the side shell and are to taken as follows, *see Figure 2.4.3 Loads to be applied to side shell structure*

B_{ss} = mean breadth of the supported deck plating, i.e. half the transverse distance from the side shell to longitudinal bulkheads, or effectively supported longitudinal girders, in metres

S_{ss} = length of the side shell between major transverse bulkheads, in metres.

4.2.6 The design global shear force is to be taken as Q_D, as defined in *Vol 1, Pt 7, Ch 2, 3.3 Design global loads – Intact conditions* or *Vol 1, Pt 7, Ch 2, 3.4 Design global loads – Damaged conditions or Residual Strength Assessment (RSA) conditions*

4.2.7 The design loads for side shell primary members are given in *Vol 1, Pt 7, Ch 2, 4.8 Longitudinal stringers (ST)* for longitudinal stringers and in *Vol 1, Pt 7, Ch 2, 5.5 Side frames and web frames (SF)* for side frames and web frames.

4.3 Strength deck and internal deck structures (DK)

4.3.1 The design normal pressure, P_{DK}, for the deck plating and stiffeners is to be taken as the greater of the following, provided that the load component is applicable:

(a) P_{WD} (weather deck pressure), *see Vol 1, Pt 7, Ch 2, 3.6 External shell pressures 3.6.2*
(b) P_{ID} (interior deck pressure), *see Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.3*
(c) P_{CD} (cargo deck pressure), *see Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.2*
(d) P_{tk} (deep tank boundary, where appropriate).

4.3.2 For loading conditions which represent damaged situations and for decks that form part of the watertight subdivision, the design normal pressure, P_{DK}, is to be taken as follows if this is greater than *Vol 1, Pt 7, Ch 2, 4.3 Strength deck and internal deck structures (DK) 4.3.1*:

(a) P_{da} (damage head).

4.3.3 The design load matrix, $[F_{DK}]$, in kN for the deck plating and stiffeners is to be taken as the combination of the following, as appropriate:

$[F_{CD}]$ = *see Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.5* (equipment or other deck loads)

L_A = pillar loads from above, if not transferred to pillars below, *see Vol 1, Pt 7, Ch 2, 4.2 Side shell structures (SS) 4.2.5*

These loads are to be applied in addition to the design pressures above.

4.3.4 Normally, the design impulse pressure, $I\,P_{DK}$, for the deck plating and stiffeners may be ignored. However, the design impulse pressure will need to be considered for decks designed to withstand helicopter or aircraft landing operations, cargo handling at sea or similar.

4.3.5 The design global vertical bending moment is to be taken as M_D, as defined in *Vol 1, Pt 7, Ch 2, 3.3 Design global loads – Intact conditions* or *Vol 1, Pt 7, Ch 2, 3.4 Design global loads – Damaged conditions or Residual Strength Assessment (RSA) conditions*.

4.3.6 The design transverse load, LT_{DK}, due to hydrostatic and hydrodynamic compressive loading is to be taken as follows, *see also Vol 1, Pt 7, Ch 2, 4.3 Strength deck and internal deck structures (DK) 4.3.8*:

$$LT_{DK} = -\varepsilon_{DK}\, P_{SS}\, H_d\, S_{dk} \text{ kN}$$

where

H_d = half the vertical distance from the first full breadth deck below the deck under consideration to the first full breadth deck above this deck, or to the strength deck if there are no decks above, in metres

S_{dk} = length of the side shell plating between major transverse bulkheads, in m, *see Figure 2.4.4 Design loads for the deck structure*

ε_{DK} = effectiveness of the deck, i.e. the relative proportion of the load carried by the deck as opposed to other structure such as bulkheads

= 0,8

P_{SS} is to be taken at the mid height of the H_d depth, P_{SS} is defined in *Vol 1, Pt 7, Ch 2, 3.6 External shell pressures 3.6.1*

H_d is illustrated in *Figure 2.4.2 Design parameter Hd for transverse load*

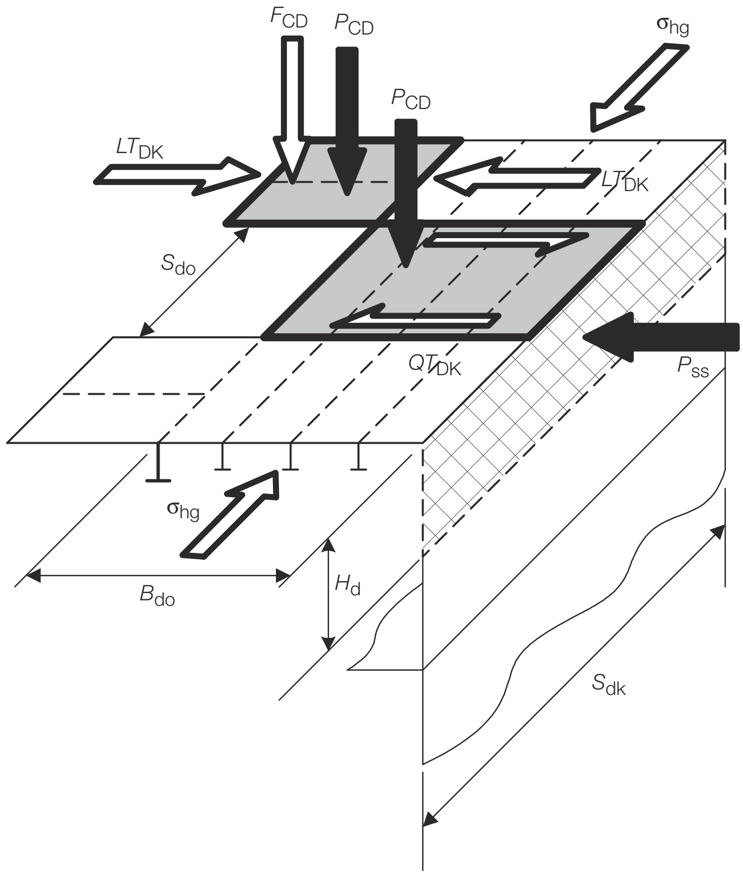


Figure 2.4.4 Design loads for the deck structure

4.3.7 Normally, the design global shear force may be ignored for the deck plating. However if the structural arrangement is such that significant shear load is carried by the deck, then it should be considered. In this case the design global shear force is to be taken as Q_D, as defined in *Vol 1, Pt 7, Ch 2, 3.3 Design global loads – Intact conditions* or *Vol 1, Pt 7, Ch 2, 3.4 Design global loads – Damaged conditions or Residual Strength Assessment (RSA) conditions*

4.3.8 If the deck is not continuous across the full breadth, due to the presence of large openings, then LT_{DK} may be taken as zero over the opening breadth. In this case it may be necessary to consider the local shear force in the deck plating due to hydrostatic and hydrodynamic loading on the longitudinal span of the deck. This shear force acts in the transverse direction and is to be taken as:

$$QT_{DK} = P_{SS} H_d S_{do}/2 \text{ kN}$$

where

S_{do} = length of the deck plating between major transverse bulkheads or the length of the deck opening, whichever is lesser, in metres

P_{SS} and H_d are defined in *Vol 1, Pt 7, Ch 2, 4.3 Strength deck and internal deck structures (DK) 4.3.6*

The shear area of the deck plate supporting this shear load is to be based on the breadth of the deck edge strip, B_{do}.

4.3.9 The transverse load, LT_{DK}, in way of the full breadth decks at the ends of the deck opening is to be increased by the ratio:

$$S_d/(S_d - S_{do})$$

The efficiency of the deck, ε_{DK} *see Vol 1, Pt 7, Ch 2, 4.3 Strength deck and internal deck structures (DK) 4.3.6*, may be reduced provided that the transverse bulkheads are capable of carrying more of the transverse loading.

4.3.10 The design loads for deck primary members are given in *Vol 1, Pt 7, Ch 2, 4.7 Deck girders (DG)* for deck girders and in *Vol 1, Pt 7, Ch 2, 5.6 Deck beams (BM)* for deck beams.

4.4 Inner bottom structures (IB)

4.4.1 For all loading conditions, the design normal pressure, P_{IB}, for the inner bottom plating and stiffeners is to be taken as the greater of:

(a) P_{ID} (interior deck pressure), *see Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.3*

(b) P_{CD} (cargo deck pressure), *see Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.2*

(c) P_{tk} (deep tank pressure, where appropriate).

4.4.2 For loading conditions which represent damaged situations, the design normal pressure, P_{IB}, for the inner bottom plating and stiffeners is to be taken as the greater of the following. If this is greater than *Vol 1, Pt 7, Ch 2, 4.4 Inner bottom structures (IB) 4.4.1*:

(a) P_{da} (damage head).

(b) P_{SS} (pressure on shell plating, where appropriate).

4.4.3 The design load matrix, [F_{IB}], in kN for the inner bottom plating and stiffeners is to be taken as:

[F_{CD}] (equipment or other deck loads), *see Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.5*

4.4.4 The design impulse pressure for the inner bottom plating and stiffeners may be ignored.

4.4.5 The design global vertical bending moment for the inner bottom plating and stiffeners is to be taken as M_D, as defined in *Vol 1, Pt 7, Ch 2, 3.3 Design global loads – Intact conditions* or *Vol 1, Pt 7, Ch 2, 3.4 Design global loads – Damaged conditions or Residual Strength Assessment (RSA) conditions*.

4.4.6 The design transverse load, LT_{IB}, due to hydrostatic and hydrodynamic compressive loading is to be taken as follows:

$$LT_{IB} = -\varepsilon_{IB} P_{SS} H_d S_{ib} \text{ kN}$$

where

H_d = half the vertical distance from the keel to the first full breadth deck above the inner bottom, in metres

S_{ib} = span of the bottom shell plating between major transverse bulkheads, in metres, *see Figure 2.4.5 Loads to be applied to inner bottom plating*

ε_{IB} = effectiveness of the inner bottom, i.e. the relative proportion of the load carried by the inner bottom as opposed to other structure such as the bottom shell, floors and bulkheads

= 0,5 normally

P_{SS} is to be taken at a height of $H_d/2$ above the keel, P_{SS} is defined in *Vol 1, Pt 7, Ch 2, 3.6 External shell pressures*

H_d is illustrated in *Figure 2.4.2 Design parameter Hd for transverse load*

4.4.7 The design global shear force, Q_D, may be ignored for the inner bottom plating.

4.4.8 The design loads for inner bottom structure primary members are given in *Vol 1, Pt 7, Ch 2, 4.6 Bottom longitudinal girders (BG)* for bottom longitudinal girders and in *Vol 1, Pt 7, Ch 2, 5.4 Transverse floors (FL)* for transverse floors.

4.5 Longitudinal bulkhead structures (LB)

4.5.1 The design normal pressure for longitudinal bulkhead plating with longitudinal stiffeners is to be taken as the same for both the plating and stiffeners. The design normal pressure, P_{LB}, is to be taken as $P_{B\ \text{HP}}$ as given in *Vol 1, Pt 7, Ch 2, 5.2 Transverse watertight and deep tank bulkheads (BH) 5.2.1*

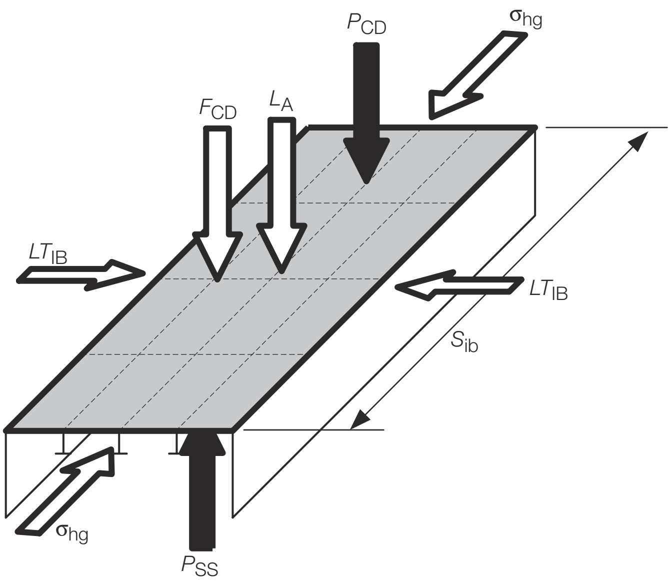


Figure 2.4.5 Loads to be applied to inner bottom plating

4.5.2 The design normal pressure for longitudinal bulkhead plating with vertical stiffeners is to be considered separately for the plating and the vertical stiffeners. The design normal pressure for the plating, P_{LB}, is to be taken as P_{BHP} as given in *Vol 1, Pt 7, Ch 2, 5.2 Transverse watertight and deep tank bulkheads (BH) 5.2.1*. The design normal pressure for the stiffener, P_{LBS}, is to be taken as P_{BHS} as given in *Vol 1, Pt 7, Ch 2, 5.2 Transverse watertight and deep tank bulkheads (BH) 5.2.1*

4.5.3 The design impulse pressure, $I\ P_{\text{LB}}$, for the longitudinal bulkhead plating and stiffeners may be ignored, unless these members are likely to be subjected to significant sloshing loads or similar.

4.5.4 The design global vertical bending moment for longitudinal bulkhead plating and stiffeners is to be taken as M_{D} as defined in *Vol 1, Pt 7, Ch 2, 3.3 Design global loads – Intact conditions* or *Vol 1, Pt 7, Ch 2, 3.4 Design global loads – Damaged conditions or Residual Strength Assessment (RSA) conditions*

4.5.5 The design vertical load, LV_{LB}, at each intersecting deck level is to derived as follows:

$$LV_{\text{LB}} = -\left(S_{\text{lb}}\, B_{\text{lb}}\, P_{\text{CD}} + L_{\text{A}} + [F_{\text{CD}}] \right) \text{ kN}$$

where

P_{CD} = inertial deck design pressure, as appropriate, plus any other local loadings directly above the pillar, in kN/m^2, *see Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.2*

$[F_{\text{CD}}]$ = inertial load or loads, in kN, from items of equipment, etc. on the supported deck, assumed zero if there is none over. F_{CD} is defined in *Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.5*

L_{A} = appropriate portion of the load or loads, in kN, from pillar(s) or bulkhead(s) above, assumed zero if there is none over, *see also Vol 1, Pt 7, Ch 2, 4.2 Side shell structures (SS) 4.2.5*

$S_{\text{lb}}\ B_{\text{lb}}$ is the effective deck area supported by the longitudinal bulkhead and can be taken as follows, *see Figure 2.4.6 Loads to be applied to longitudinal bulkhead plating*

B_{lb} = mean spacing of longitudinal bulkheads, side shell or effectively supported longitudinal girders, in metres.

S_{lb} = span or length of the longitudinal bulkhead between major transverse bulkheads, in metres.

4.5.6 The design global shear force for longitudinal bulkhead plating is to be taken as Q_{D}, as defined in *Vol 1, Pt 7, Ch 2, 3.3 Design global loads – Intact conditions* or *Vol 1, Pt 7, Ch 2, 3.4 Design global loads – Damaged conditions or Residual Strength Assessment (RSA) conditions*.

4.5.7 If the longitudinal bulkhead is not continuous over the full depth of the ship then it will be necessary to consider the local shear force in the longitudinal bulkhead plating as the vertical load must be transferred into the supporting structure, such as transverse bulkheads. This shear force acts in the vertical direction and is to be taken as:

$$QV_{\text{LB}} = LV_{\text{LB}}/2$$

The shear area of the longitudinal bulkhead plate supporting this shear load is to be based on the depth of the longitudinal bulkhead between decks.

4.5.8 The design loads for longitudinal bulkhead primary members are given in *Vol 1, Pt 7, Ch 2, 4.8 Longitudinal stringers (ST)* for longitudinal stringers and in *Vol 1, Pt 7, Ch 2, 5.5 Side frames and web frames (SF)* for side frames and web frames.

4.6 Bottom longitudinal girders (BG)

4.6.1 This sub-Section covers double bottom and single bottom girders. *Figure 2.4.7 Loads to be applied to bottom girders* illustrates the design loads.

4.6.2 The design normal pressure, P_{BG}, for girder web plating is to be taken as the greater of:

(a) P_{tk} kN/m^2 (Deep Tank, if applicable), *see Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.4*

(b) P_{da} kN/m^2 (WT subdivision, only if applicable and for loading conditions which represent damaged situations), *see Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.4*

(c) 5,0 (minimum value for no direct loading).

4.6.3 The design impulse pressure, $I\,P_{\text{BG}}$, for the bottom girder web plating may be ignored, unless these members are subjected to sloshing loads or similar.

4.6.4 The design global vertical bending moment for bottom girder plating and stiffeners is to be taken as M_{D}, as defined in *Vol 1, Pt 7, Ch 2, 3.3 Design global loads – Intact conditions* or *Vol 1, Pt 7, Ch 2, 3.4 Design global loads – Damaged conditions or Residual Strength Assessment (RSA) conditions*

4.6.5 The design vertical load, LV_{BG}, acting on the web plating of bottom girders is to be based on the supported loads. Typically these include downwards local inertial pressures, P_{CD}, inertial forces, [F_{CD}], and pillar bulkhead loads above, L_{A}, all acting on the plating of the inner bottom or the bottom girder flange and the upwards buoyancy loads on the bottom shell plating, P_{BS}. The design vertical load is to be taken as:

$$LV_{\text{BG}} = -\varepsilon_{\text{BG}}\,(B_{\text{bg}}\,S_{\text{bg}}\,(P_{\text{CD}} - P_{\text{BS}}) + [F_{\text{CD}}] + L_{\text{A}})\ \text{kN}$$

where

ε_{BG} = effectiveness of the bottom girders, i.e. the relative proportion of the load carried by the bottom girders as opposed to other structure such as the transverse floors

= 0,5

B_{bg} = mean spacing of longitudinal girders or other primary longitudinal structure, in metres, *see* Note 2

S_{bg} = span or length of the longitudinal girder between transverse bulkheads, in metres

L_{A} = load, in kN, from pillar(s) above, assumed zero if there is none over, *see Vol 1, Pt 7, Ch 2, 4.2 Side shell structures (SS) 4.2.5*

F_{CD} = inertial load or loads, in kN, from items of equipment, etc on the supported deck, assumed zero if there is none over. F_{CD} is defined in *Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.5*

P_{BS} is defined in *Vol 1, Pt 7, Ch 2, 4.1 Bottom shell structures (BS) 4.1.2*

P_{CD} is defined in *Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.2*

Note 1. For single bottom girders P_{CD} is likely to be zero. In this situation B_{bg} = span or length of the longitudinal girder between transverse bulkheads. P_{CD} should be taken as the distributed machinery load, if it is not included in [F_{CD}].

Note 2. Where the girder is part of a longitudinally stiffened bottom structure with closely spaced floors, the mean spacing B_{bg} may be taken as the spacing of the longitudinal stiffeners. For grillage or transversely stiffened systems then the spacing is to be taken as stated.

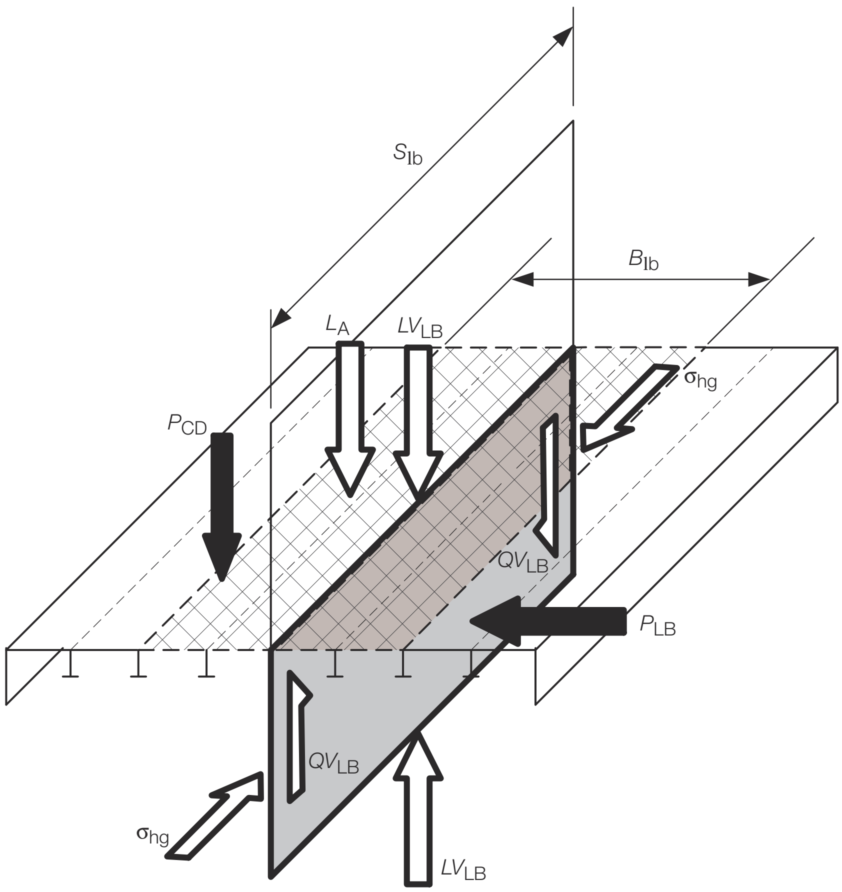


Figure 2.4.6 Loads to be applied to longitudinal bulkhead plating

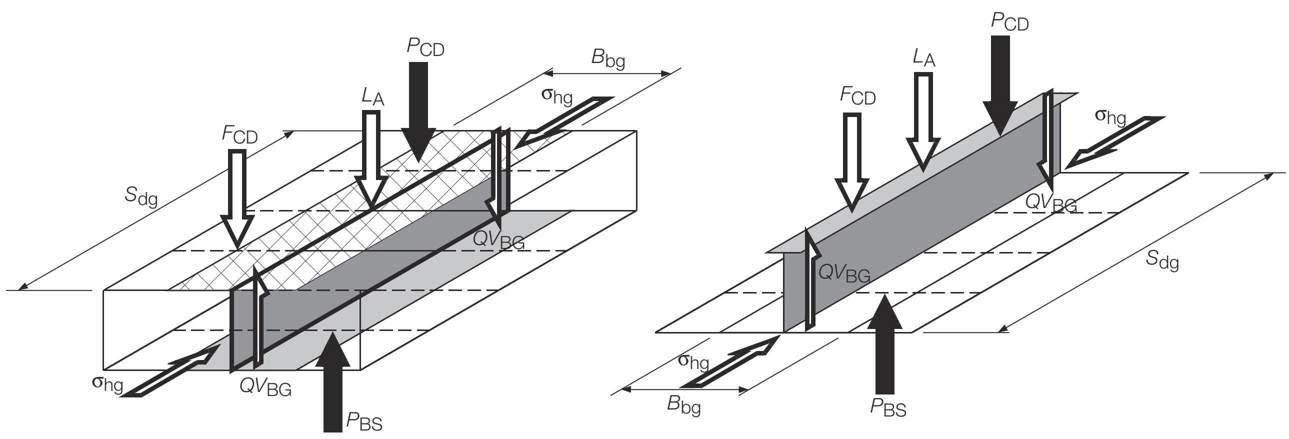


Figure 2.4.7 Loads to be applied to bottom girders

4.6.6 The design shear force for the bottom girder web plating is to include local and global components.

(a) The design global shear force is to be taken as Q_D, as defined in *Vol 1, Pt 7, Ch 2, 3.3 Design global loads – Intact conditions* or *Vol 1, Pt 7, Ch 2, 3.4 Design global loads – Damaged conditions or Residual Strength Assessment (RSA) conditions*. If the girder depth is reasonably small then Q_D may be ignored.

(b) The local shear force component, QV_{BG}, is due to the difference between the buoyancy and the inertial forces. It acts in the vertical direction and is to be taken as:

$$QV_{BG} = \varepsilon_{BG} (B_{bg} S_{bg} (P_{CD} - P_{BS}) + [F_{CD}] + LA)/2$$

where

B_{bg} = mean spacing of longitudinal girders or other primary longitudinal structure, in metres, *see* Note 2.

4.6.7 The design bending load for bottom girder primary member is to be taken as:

$\varepsilon_{BG} (B_{bg} S_{bg} (P_{CD} - P_{BS}) + [F_{CD}] + L_A)$ kN

4.6.8 The membrane loads acting on the bottom shell plating are defined in *Vol 1, Pt 7, Ch 2, 4.1 Bottom shell structures (BS)* The membrane loads acting on the inner bottom plating are defined in *Vol 1, Pt 7, Ch 2, 4.4 Inner bottom structures (IB)*. These loads are required to assess the bottom girder beam in addition to the local bending loads.

4.7 Deck girders (DG)

4.7.1 The design normal pressure, P_{DG}, for deck girder web plating may be ignored.

4.7.2 The design impulse pressure, $I\,P_{DG}$, for deck girder web plating may be ignored, unless these members are subjected to sloshing loads or similar.

4.7.3 The design global vertical bending moment for deck girders is to be taken as M_D, as defined in *Vol 1, Pt 7, Ch 2, 3.3 Design global loads – Intact conditions* or *Vol 1, Pt 7, Ch 2, 3.4 Design global loads – Damaged conditions or Residual Strength Assessment (RSA) conditions*.

4.7.4 The design vertical load for deck girder webs may be ignored.

4.7.5 The design shear force for the deck girder web plating is to include local and global components.

(a) The design global shear force is to be taken as Q_D, as defined in *Vol 1, Pt 7, Ch 2, 3.3 Design global loads – Intact conditions* or *Vol 1, Pt 7, Ch 2, 3.4 Design global loads – Damaged conditions or Residual Strength Assessment (RSA) conditions*. If the girder depth is reasonably small then Q_D may be ignored.

(b) The local shear force component, QV_{DG}, is due to the difference between the buoyancy and the inertial forces. It acts in the vertical direction and is to be taken as:

QV_{DG} = ε_{BG} (B_{dg} S_{dg} P_{CD} + [F_{CD}] + L_A)/2 kN

where

ε_{BG} = effectiveness of the deck girders, i.e. the relative proportion of the load carried by the deck girders as opposed to other structure such as the deck beams

= 0,5

B_{dg} = mean spacing of longitudinal girders or other primary longitudinal structure, in metres, *see Figure 2.4.8 Loads to be applied to deck girders*

S_{dg} = span or length of the longitudinal girder between transverse bulkheads, in metres

L_A = load, in kN, from pillar(s) above, assumed zero if there is none over

F_{CD} = inertial load or loads, in kN, from items of equipment, etc. on the supported deck, assumed zero if there is none over. F_{CD} is defined in *Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.5*

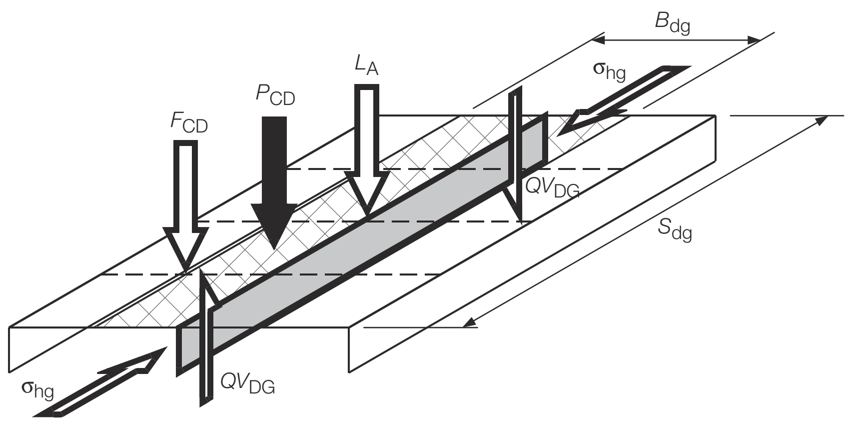


Figure 2.4.8 Loads to be applied to deck girders

4.7.6 The membrane loads acting on the deck plating are defined in *Vol 1, Pt 7, Ch 2, 4.3 Strength deck and internal deck structures (DK)*

4.7.7 The design bending load for the deck girder primary member is to be taken as:

ε_{BG} (B_{dg} S_{dg} P_{CD} + [F_{CD}] + L_A) kN.

4.8 Longitudinal stringers (ST)

4.8.1 This sub-Section covers stringers supporting side shell plating, horizontal girders on longitudinal bulkheads and also covers horizontal diaphragms fitted between a double skin. The design loads are illustrated in *Figure 2.4.9 Design loads for longitudinal stringers*

4.8.2 The design normal pressure, P_{ST}, for the web plating of stringer may be ignored unless the stringer forms part of a tank boundary or watertight subdivision, i.e. a watertight horizontal diaphragm. In this case the design pressure is to be taken as the greater of

(a) P_{tk} kN/m^2 (Deep Tank, if applicable), *see Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.4*
(b) P_{da} kN/m^2 (WT subdivision, only if applicable and for loading conditions which represent damaged situations), *see Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.4*.
(c) 5,0 (minimum value for no direct loading).

4.8.3 The design impulse pressure, $I\ P_{ST}$, for the web plating of stringer may be ignored, unless these members are subjected to sloshing loads or similar.

4.8.4 The design global vertical bending moment for longitudinal stringers is to be taken as M_D, as defined in *Vol 1, Pt 7, Ch 2, 3.3 Design global loads – Intact conditions* or *Vol 1, Pt 7, Ch 2, 3.4 Design global loads – Damaged conditions or Residual Strength Assessment (RSA) conditions*

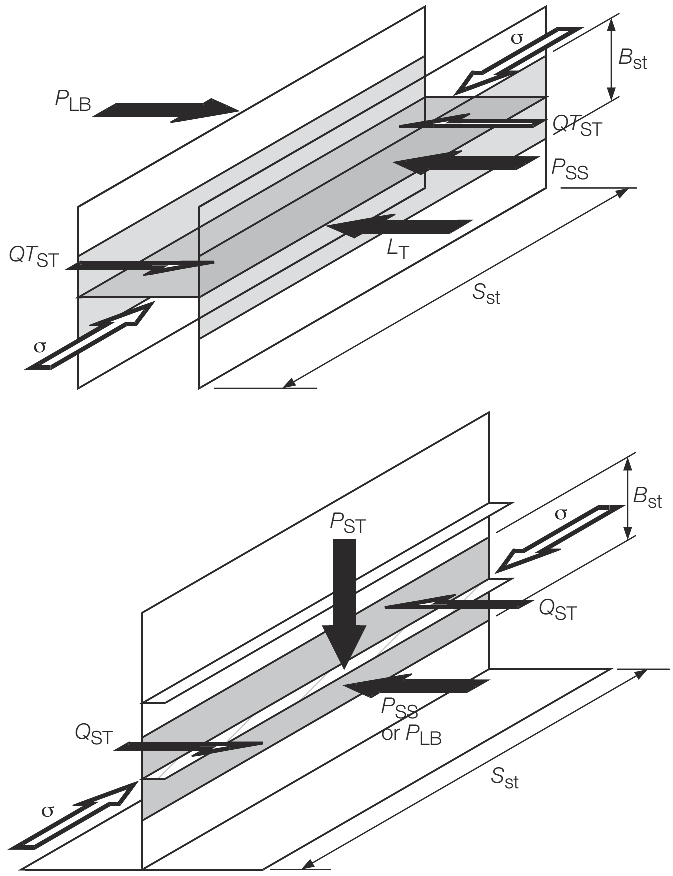


Figure 2.4.9 Design loads for longitudinal stringers

4.8.5 The design transverse load, LT_{ST}, acting on the web plating of horizontal diaphragms is to be based on the pressure loads acting on the plating of the inner skin or longitudinal bulkhead P_{LB} (outwards) and the side shell P_{SS} (inwards). The design transverse load, LT_{ST}, is to be taken as the lesser of:

(a) $-\varepsilon_{ST}\ B_{st}\ S_{st}\ P_{SS}$ kN
(b) $-\varepsilon_{ST}\ B_{st}\ S_{st}\ P_{LB}$ kN

where

ε_{ST} = effectiveness of the horizontal diaphragms, i.e. the relative proportion of the load carried by the horizontal diaphragms as opposed to other structure such as the transverse web or normal frames

= 0,5

H_{st} = mean spacing, in metres, of stringers (or horizontal girders) and other primary horizontal structure, i.e. decks or similar

S_{st} = length of the stringer (or horizontal girder) between transverse bulkheads, in m, *see Figure 2.4.9 Design loads for longitudinal stringers*

P_{SS} is to be taken as the side shell pressure at the height of the stringer, *see Vol 1, Pt 7, Ch 2, 3.6 External shell pressures 3.6.1*. P_{SS} is to be ignored for horizontal girders attached to longitudinal bulkheads.

P_{LB} is to be taken as the longitudinal bulkhead normal pressure at the height of the horizontal girder, *see Vol 1, Pt 7, Ch 2, 4.5 Longitudinal bulkhead structures (LB) 4.5.1* This is only required for longitudinal bulkheads that form part of a deep tank or watertight boundary.

> Note Where the horizontal diaphragm is part of a longitudinally stiffened structure with regular transverse webs, the mean spacing H_{st} may be based on the longitudinal spacing. For grillage or transversely stiffened systems then the spacing is to be taken as originally stated.

4.8.6 The design transverse load, LT_{ST}, for stringers and horizontal girders may be ignored.

4.8.7 The design shear force, QT_{ST}, in the stringer web due to hydrostatic, hydrodynamic or tank loading acts in the transverse direction is to be taken as the greater of:

(a) $\varepsilon_{ST} H_{st} S_{st} P_{SS}/2$
(b) $\varepsilon_{ST} H_{st} S_{st} P_{LB}/2$

where

H_{st} = mean spacing, in metres, of stringers (or horizontal girders) and other primary horizontal structure, i.e. decks or similar.

4.8.8 The design bending load for the deck girder primary member is to be taken as:

(a) $\varepsilon_{ST} H_{st} S_{st} (P_{SS} - P_{LB})$

where

H_{st} = mean spacing, in metres, of stringers (or horizontal girders) and other primary horizontal structure, i.e. decks or similar.

4.8.9 The membrane loads acting on the side shell and longitudinal bulkhead plating are defined in *Vol 1, Pt 7, Ch 2, 4.2 Side shell structures (SS)* and *Vol 1, Pt 7, Ch 2, 4.5 Longitudinal bulkhead structures (LB)*, these loads are required to assess the longitudinal stringer beam in addition to the local bending loads.

■ *Section 5*
Design load systems for structural components or longitudinally ineffective material

5.1 Deck structures (DK)

5.1.1 The design pressure, P_{WD}, for weather deck structure is given in *Vol 1, Pt 7, Ch 2, 3.6 External shell pressures 3.6.2*.

5.1.2 For weather decks and interior decks subjected to cargo loads or other pressure loading then the following design pressure is to be used for the plating and stiffeners if it is greater than that given in *Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.1*:

$$P_{CD} = w_f W_{cd} \text{ kN/m}^2$$

where

W_{cd} is the static pressure exerted by the cargo, payload, stores or equipment on the deck as specified by the designer in kN/m^2, *see Vol 1, Pt 7, Ch 2, 2.1 Nomenclature 2.1.2* and *see also Vol 1, Pt 5, Ch 3, 5.4 Loads for decks designed for cargo or heavy equipment loads, Pcd and Wcd 5.4.1*

w_f is given in *Vol 1, Pt 7, Ch 2, 3.5 Inertial force load combination factor, wf 3.5.1*

5.1.3 The design pressure, P_{ID}, for interior deck plating and stiffeners is given by:

$$P_{ID} = w_f W_{in} \text{ kN/m}^2$$

P_{ID} is not to be taken less than 2,5 kN/m^2

W_{in} is defined in *Vol 1, Pt 7, Ch 2, 2.1 Nomenclature 2.1.2*

5.1.4 For weather or internal decks which form part of a deep tank or watertight boundary then the pressure loading is to be taken as the greater of the following if this is greater than the above:

P_{tk} = $9,81\rho\,(H_{tk} - z)$ kN/m^2 (deep tank, if applicable)

P_{da} = $10(H_{da} - z)$ kN/m^2 (WT subdivision, only if applicable and for loading conditions which represent damaged situations)

where

ρ = specific density of liquid in the tank, to be taken as not less than 1,025

z = distance above the baseline of the mid depth of the deck plating

H_{tk} and H_{da} are defined in *Vol 1, Pt 7, Ch 2, 2.1 Nomenclature 2.1.2*

5.1.5 The cargo deck design force matrix, $[F_{CD}]$, for plating and stiffeners is to be taken as below for all mass items which act over the deck area considered

(a) $[F_{CD}] = w_f\,[W_{ma}]$

W_{ma} is the weight of each item on the deck as specified by the designer in kN. *See also Vol 1, Pt 5, Ch 3, 5.4 Loads for decks designed for cargo or heavy equipment loads, Pcd and Wcd 5.4.2*

5.1.6 If the deck is required to be immersed during its operation, e.g. an internal dock area, then the deck is to be designed using the side shell pressure loads, P_{SS}, *see Vol 1, Pt 7, Ch 2, 3.6 External shell pressures 3.6.1*

5.2 Transverse watertight and deep tank bulkheads (BH)

5.2.1 The design normal pressure for bulkhead plating, P_{BHP}, and stiffeners, P_{BHS}, is to be taken as the pressure values P_{bhp} and P_{bhs} respectively given in *Vol 1, Pt 5, Ch 3, 5.8 Design pressures for watertight and deep tank bulkheads and boundaries*

5.2.2 The design impulse pressure, $I\,P_{BH}$, for the bulkhead plating and stiffeners may be ignored, unless these members are likely to be subjected to significant sloshing loads or similar.

5.2.3 The design transverse load, LT_{BH}, due to hydrostatic and hydrodynamic compressive loading is to be taken as follows:

$$LT_{BH} = -\varepsilon_{BH}\,P_{SS}\,H_{bh}\,S_{bh}\ \text{kN}$$

where

H_{bh} = half the vertical distance from the deck below the bulkhead under consideration to the deck above, in metres, *see Figure 2.5.1 Design parameter H_{bh} for transverse loads* and *Figure 2.5.2 Design loads for bulkheads*

S_{bh} = half the longitudinal distance between adjacent transverse bulkheads, in metres

ε_{BH} = effectiveness of the bulkhead, i.e. the relative proportion of the load carried by the bulkhead as opposed to other structure such as decks

ε_{BH} may be taken as 0,5

alternatively ε_{BH} may be taken as

ε_{BH} = $H_{bh}/(2S_{bh})$ for $H_{bh} < S_{bh}$

and = $1 - S_{bh}/(2H_{bh})$ for $H_{bh} > S_{bh}$

P_{SS} is to be taken at the mid height of the H_{bh} depth, P_{SS} is defined in *Vol 1, Pt 7, Ch 2, 3.6 External shell pressures 3.6.1*

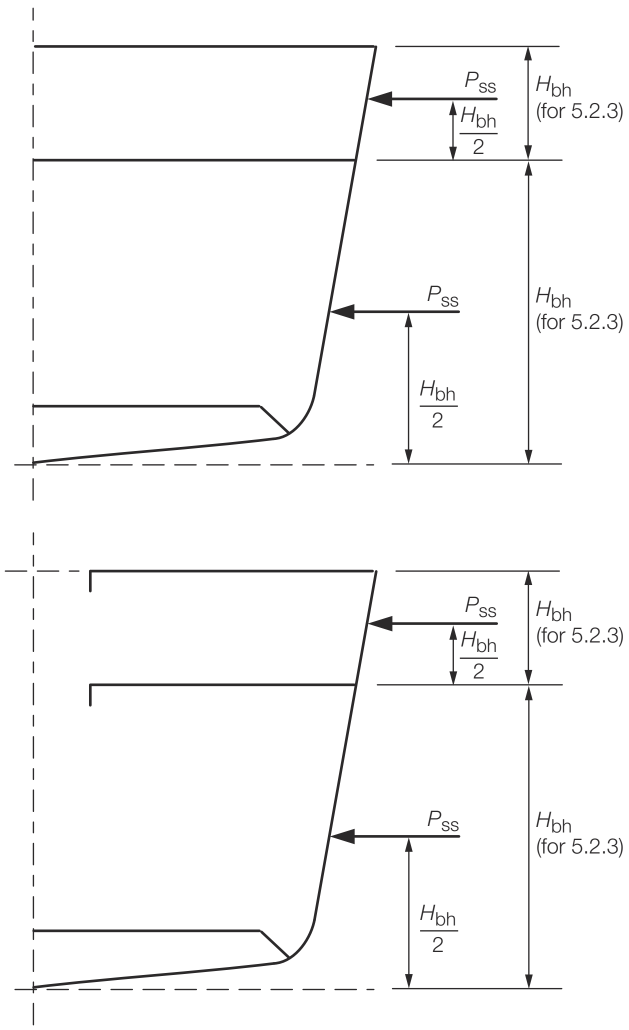


Figure 2.5.1 Design parameter H_{bh} for transverse loads

5.2.4 The design vertical load, LV_{BH}, supported by the transverse bulkheads is to be based on the pressure loads acting on the plating of the supported deck over, P_{CD}, the local inertial forces, $[F_{CD}]$, and the bulkhead loads above, L_A. The design vertical load is to be taken as

$$LV_{BH} = -(B_{bh} S_{bh} P_{CD} + [F_{CD}] + L_A) \text{ kN}$$

where

B_{bh} = breadth of the deck supported by the bulkhead, in metres

L_A = load, in kN, the bulkhead above, assumed zero if there are is over, *see Vol 1, Pt 7, Ch 2, 4.2 Side shell structures (SS) 4.2.5*

F_{CD} = inertial load or loads, in kN, from items of equipment, etc. on the supported deck, assumed zero if there is none over. F_{CD} is defined in *Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.5*

P_{CD} is defined in *Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.2*

5.2.5 Normally, the design shear force, QV_{BH}, may be ignored for bulkhead plating. However, if the structural arrangement or load paths are such that significant shear load is carried by the bulkhead, then it should be considered, e.g. when the bulkhead is not continued down to the bottom shell. In this case the design shear force, acting in the vertical direction, is to be taken as

$QV_{BH} = LV_{BH}/2$ kN

where

LV_{BH} is given in *Vol 1, Pt 7, Ch 2, 5.2 Transverse watertight and deep tank bulkheads (BH) 5.2.4*

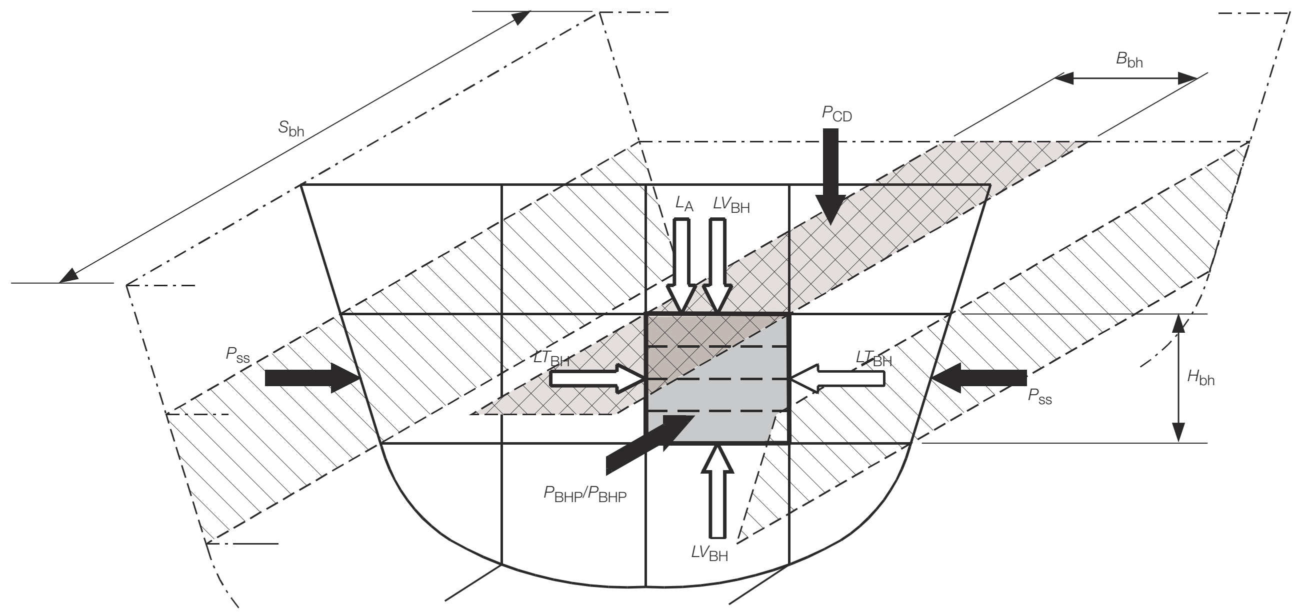


Figure 2.5.2 Design loads for bulkheads

5.3 Deckhouses, bulwarks and superstructures (DH)

5.3.1 The design normal pressure, P_{DH}, for the plating and stiffeners of deckhouses, bulwarks and the first tier and above of superstructures is given by:

$$P_{DH} = P_{dh} \text{ kN/m}^2$$

5.3.2 For the side plating and longitudinal bulkheads of deckhouses and superstructures, the design vertical load, LV_{DH}, at each intersecting deck level is to be taken as follows: $LV_{DH} = -\varepsilon_{DH}(S_{dh} B_{dh} P_{CD} + L_A + [F_{CD}])$ kN

where

P_{CD} = basic deck design pressure, as appropriate, plus any other local loadings directly above the pillar, in kN/m^2

$[F_{CD}]$ = inertial load or loads, in kN, from items of equipment, etc. on the supported deck, assumed zero if there is none over. F_{CD} is defined in *Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.5*

L_A = appropriate portion of the load or loads, in kN, from pillar(s) or bulkhead(s) above, assumed zero if there is none over, *see Vol 1, Pt 7, Ch 2, 4.2 Side shell structures (SS) 4.2.5*

ε_{DH} = effectiveness of the side plating or longitudinal bulkhead, i.e. the relative proportion of the load carried by this plating as opposed to other structure such as the transverse bulkheads

= 0,5

S_{dh} B_{dh} is the effective deck area supported by the deckhouse side plating or longitudinal bulkheads and can be taken as follows:

B_{dh} = mean spacing of longitudinal bulkheads, side shell or effectively supported longitudinal girders, in metres.

S_{dh} = span or length of the side plating or longitudinal bulkhead between major deckhouse transverse bulkheads, in metres.

5.3.3 For transverse bulkheads of deckhouses and superstructures, the design vertical load, LV_{DH}, at each intersecting deck level is to be taken as follows:

$$LV_{DH} = -\varepsilon_{DH} (S_{dh} B_{dh} P_{CD} + L_A + [F_{CD}]) \text{ kN}$$

where

ε_{DH} = efficiency of the transverse bulkheads i.e. the relative proportion of the load carried by the transverse bulkheads as opposed to other structure such as the side plating

= 0,5

$S_{dh} B_{dh}$ is the effective deck area supported by the transverse bulkhead and can be taken as follows:

S_{dh} = mean spacing of transverse bulkheads, in metres.

B_{dh} = breadth of the transverse bulkhead, in metres.

5.3.4 For decks of deckhouses, the design transverse load, LT_{DH}, at each deck level may normally be ignored.

5.3.5 If the superstructure or deckhouse is longitudinally effective then the design global vertical bending moment and shear force are to be taken as M_D and Q_D respectively, *see Vol 1, Pt 7, Ch 2, 3.3 Design global loads – Intact conditions* or *Vol 1, Pt 7, Ch 2, 3.4 Design global loads – Damaged conditions or Residual Strength Assessment (RSA) conditions* for the design of the side plating and longitudinal bulkheads of deckhouse structures.

5.4 Transverse floors (FL)

5.4.1 The design normal pressure, P_{FL}, for the web plating of floors of double bottom or single bottom structures is to be taken as the greater of the following:

(a) P_{tk} kN/m^2 (Deep tank floor).
(b) P_{da} kN/m^2 (WT subdivision, only if applicable and for loading conditions which represent damaged situations).
(c) 5 kN/m^2 (minimum value).

where

P_{da} and P_{tk} are defined in*Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.4*

5.4.2 The design impulse pressure, $I\,P_{FL}$, for the web plating of floors may be ignored, unless these members are subjected to sloshing loads or similar.

5.4.3 The design vertical load, LV_{FL}, for the floors is to be based on the pressure loads acting on the plating of the inner bottom P_{CD} (downwards) and the bottom shell P_{BS} (upwards), the local inertial forces [F_{CD}] and pillar bulkhead loads above L_A. The design vertical load, LV_{FL}, is to be taken as:

$$LV_{FL} = -\varepsilon_{FLV} (B_{fl} S_{fl} (P_{CD} - P_{BS}) + [F_{CD}] + L_A) \text{ kN}$$

where

ε_{FLV} = effectiveness of the floors in the vertical direction, i.e. the relative proportion of the load carried by the transverse floors as opposed to bottom girders, etc.

= 1,0 for the floor halfway between transverse bulkheads

S_{fl} = mean spacing of transverse floors, in metres, *see Figure 2.5.3 Loads to be applied to transverse floors*

L_A = load, in kN, from pillar(s) or bulkhead(s) above, assumed zero if there is none over, *see Vol 1, Pt 7, Ch 2, 4.2 Side shell structures (SS) 4.2.5*

F_{CD} = inertial load or loads, in kN, from items of equipment, etc. on the supported deck, assumed zero if there is none over. F_{CD} is defined in *Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.5*

B_{fl} = breadth of the transverse floor between longitudinal bulkheads or side shell(s), in metres. NOTE B_{fl} may be full breadth

P_{BS} is defined in *Vol 1, Pt 7, Ch 2, 4.1 Bottom shell structures (BS) 4.1.2*

P_{CD} is defined in *Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.2*

Note

- For single bottom floors P_{CD} is likely to be zero.
- It may be necessary to take account of the impact loading on the bottom plating in the derivation of LV_{FL} and QV_{FL}.

5.4.4 The design transverse load, LT_{FL}, for the floor plating due to hydrostatic and hydrodynamic compressive loading is to be taken as follows:

$$LT_{FL} = -\varepsilon_{FLT} P_{SS} H_d S_{fl} \text{ kN}$$

where

ε_{FLT} = effectiveness of the floors in the transverse direction, i.e. the relative proportion of the load carried by the floor plating as opposed to other bottom structure

= $0{,}3 f_b$ for double bottom structures

= $0{,}5 f_b$ for single bottom structures

f_b = 2,0 for bottom structures where transverse elastic buckling of outer bottom plating is likely

= 3,0 for bottom structures where transverse elastic buckling of inner and outer bottom plating is likely

= 1,0 otherwise

P_{SS} and H_d are to be taken as the values defined for the bottom structure in *Vol 1, Pt 7, Ch 2, 4.1 Bottom shell structures (BS) 4.1.5*

5.4.5 The design shear force, QV_{FL}, for the floor web plating due to local loading acts in the vertical direction and is to be taken as:

$$QV_{FL} = \varepsilon_{FLV} \,(B_{fl} S_{fl} (P_{CD} - P_{BS}) + [F_{CD}] + L_A)/^2 \text{ kN}$$

5.4.6 The design bending load for bottom floor primary member is to be taken as LV_{FL}.

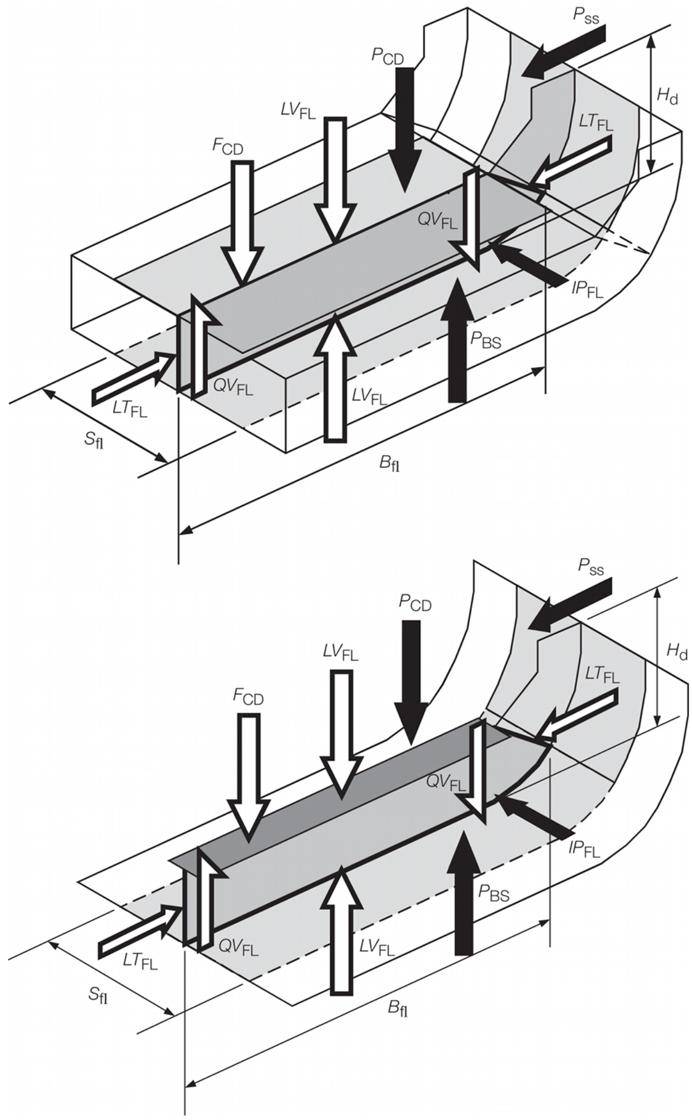


Figure 2.5.3 Loads to be applied to transverse floors

5.4.7 The membrane loads acting on the bottom shell plating are defined in *Vol 1, Pt 7, Ch 2, 4.1 Bottom shell structures (BS)*. The membrane loads acting on the inner bottom plating are defined in *Vol 1, Pt 7, Ch 2, 4.4 Inner bottom structures (IB)* These membrane loads are required to assess the transverse floors in addition to the local bending loads.

5.5 Side frames and web frames (SF)

5.5.1 This sub-Section covers side frames, web frames and frames supporting longitudinal bulkheads.

5.5.2 The design normal pressure, P_{SF}, for the web plating of side frames may be ignored.

5.5.3 The design impulse pressure, $I P_{SF}$, for the web plating of side frames may be ignored, unless these members are subjected to sloshing loads or similar.

5.5.4 The design vertical load, LV_{SF}, for the side frames, including the attached plating, is to be based on the pressure loads acting on the plating of the supported deck over, P_{CD}, the local inertial forces, $[F_{CD}]$, and side frame loads above, L_A. The design vertical load is to be taken as:

$$LV_{SF} = -(B_{fr} S_{fr} P_{CD} + [F_{CD}] + L_A) \text{ kN}$$

where

S_{fr} = mean spacing of side frames, in metres, *see Figure 2.5.4 Loads to be applied to side frames*

B_{fr} = breadth of the deck supported by the side frame, in metres

L_A = load, in kN, the side frame above, assumed zero if there is none over, *see Vol 1, Pt 7, Ch 2, 4.2 Side shell structures (SS) 4.2.5*

F_{CD} = inertial load or loads, in kN, from items of equipment, etc. on the supported deck, assumed zero if there is none over. F_{CD} is defined in *Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.5*

P_{CD} is defined in *Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.2*

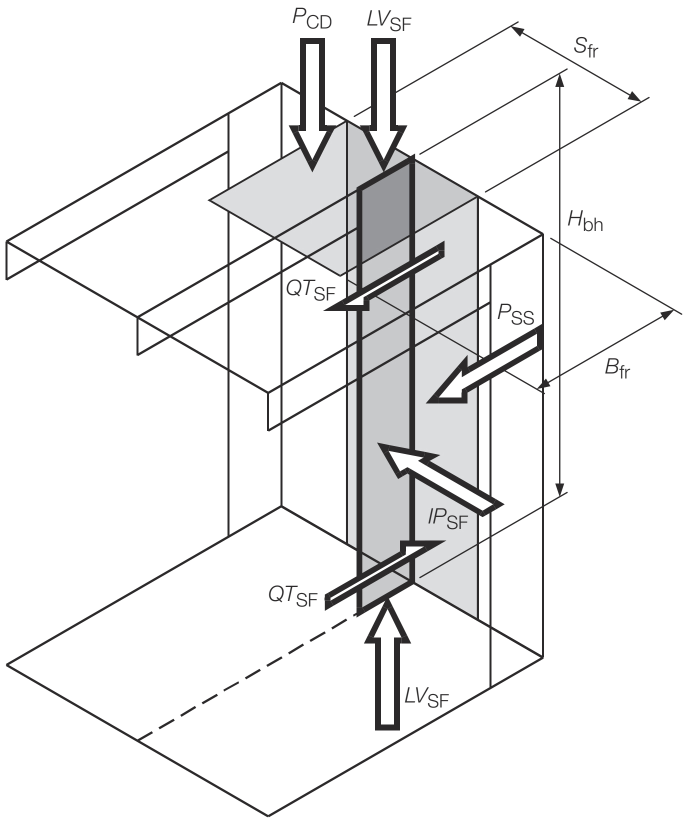


Figure 2.5.4 Loads to be applied to side frames

5.5.5 The design transverse load, LT_{SF}, may be ignored for the side frames.

5.5.6 The design shear force, QT_{SF}, for the side frame web plating due to local loading acts in the transverse direction and is to be taken as:

$$QT_{SF} = H_{fr} S_{fr} P_{SS}/2 \text{ kN}$$

where

H_{fr} = length of the side frame between adjacent decks, *see Figure 2.5.4 Loads to be applied to side frames*

P_{SS} is to be taken at the mid height of the side frame, P_{SS} is defined in *Vol 1, Pt 7, Ch 2, 3.6 External shell pressures 3.6.1*

NOTE

It may be necessary to take account of the impact loading on the side frame plating in the derivation of QT_{SF}.

5.5.7 The design bending load for side frame or web frame primary member is to be taken as:

$H_{fr} S_{fr} P_{SS}$ for frames attached to side shell

$H_{fr} S_{fr} P_{LB}$ for frames attached to longitudinal bulkheads.

5.5.8 The membrane loads acting on the side shell or longitudinal bulkhead plating are defined in *Vol 1, Pt 7, Ch 2, 4.2 Side shell structures (SS)* or *Vol 1, Pt 7, Ch 2, 4.5 Longitudinal bulkhead structures (LB)*. These membrane loads are required to assess the frames in addition to the local bending loads.

5.6 Deck beams (BM)

5.6.1 This sub-Section covers deck beams and deep transverse beams supporting deck structure.

5.6.2 The design normal pressure, P_{BM}, for the web plating of deck beams may be ignored.

5.6.3 The design impulse pressure, $I\,P_{BM}$, for the web plating of deck beams may be ignored, unless these members are subjected to sloshing loads or similar.

5.6.4 The design vertical load, LV_{BM}, for the deck beam may be ignored.

5.6.5 The design transverse load, LT_{BM}, for the deck beam due to hydrostatic and hydrodynamic compressive loading is to be taken as follows:

$LT_{BM} = -P_{SS} H_d S_{bm}$ kN

where

P_{SS} and H_d are to be taken as the values defined for the deck plating in *Vol 1, Pt 7, Ch 2, 4.3 Strength deck and internal deck structures (DK) 4.3.6*

5.6.6 The design shear force, QV_{BM}, for the deck beam web plating is to be based on the pressure loads acting on the plating of the deck P_{CD} (downwards), the local inertial forces [F_{CD}] and pillar bulkhead loads above L_A. The shear force acts in the vertical direction and is to be taken as:

$$QV_{BM} = (B_{bm} S_{bm} P_{CD} + [F_{CD}] + L_A)/2 \text{ kN}$$

where

S_{bm} = mean spacing of deck beams, in metres, *see Figure 2.5.5 Loads to be applied to deck beams*

B_{bm} = span of the deck beams between longitudinal bulkheads, pillars or side shell, in metres

L_A = load, in kN, from pillar(s) or bulkhead(s) above, assumed zero if there is none over, *see Vol 1, Pt 7, Ch 2, 4.2 Side shell structures (SS) 4.2.5*

F_{CD} = inertial load or loads, in kN, from items of equipment, etc. on the supported deck, assumed zero if there is none over. F_{CD} is defined in *Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.5*

P_{CD} is defined in *Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.2*

5.6.7 The design bending load for deck beam primary member is to be taken as:

(a) $(B_{bm} S_{bm} P_{CD} + [F_{CD}] + L_A)$ kN

5.6.8 The membrane loads acting on the deck plating are defined in *Vol 1, Pt 7, Ch 2, 4.3 Strength deck and internal deck structures (DK)* These membrane loads are required to assess the frames in addition to the local bending loads.

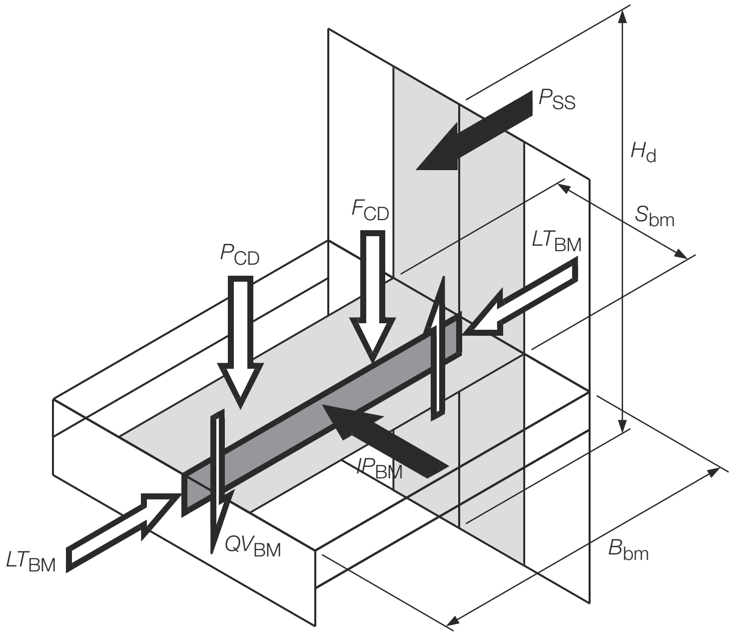


Figure 2.5.5 Loads to be applied to deck beams

5.7 Pillars (PI)

5.7.1 The design load, LV_{PI}, supported by the pillar is to be taken as:

$$LV_{PI} = -(S_{pi} B_{pi} P_{CD} + L_A + [F_{CD}]) \text{ kN}$$

where

P_{CD} = inertial deck design pressure, as appropriate, plus any other local loadings directly above the pillar, in kN/m^2. Where the pillar supports a deck area over which the design pressure varies, then the summation of the these loads is to be used, *see Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.2*

$[F_{CD}]$ = appropriate portion of the inertial load or loads, in kN, from items of equipment, etc. on the supported deck, assumed zero if there is none over. F_{CD} is defined in *Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.5*

$B_{pi} S_{pi}$ is the effective deck area supported by the pillar bulkhead

B_{pi} = mean spacing of transverses supported by pillars or transverse bulkheads, in metres, *see Figure 2.5.6 Loads supported by a pillar*

S_{pi} = mean spacing of girders supported by the pillars, longitudinal bulkheads or side shell, in metres

L_A = load, in kN, from pillar(s) or bulkhead(s) above, assumed zero if there is none over may be taken as LV_{PI} for the supported pillar or LV_{PB} for the supported bulkhead, *see Vol 1, Pt 7, Ch 2, 5.8 Pillar bulkheads (PB)*

LV_{PI} is not to be taken less than 5 kN.

5.7.2 When any of the conditions below are satisfied then the pillar load should be derived using direct calculation methods:

- where the structural arrangement is complex;

- where it is considered that the load in the pillar will not be accurately represented by the above formulae, e.g. pillars supporting decks in way of the ends of a long superstructure block;
- where the pillar is not supported underneath by the double bottom or substantial structural members.

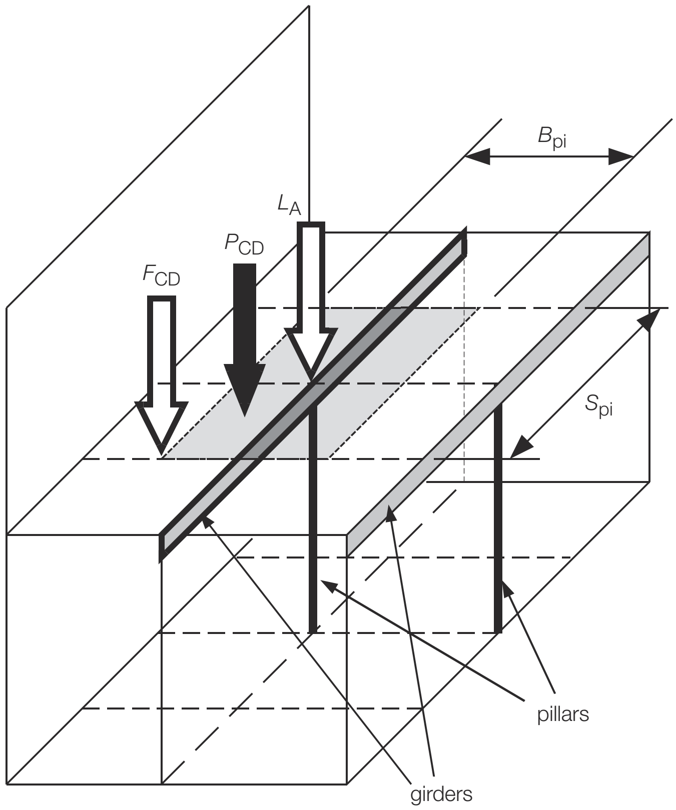


Figure 2.5.6 Loads supported by a pillar

5.8 Pillar bulkheads (PB)

5.8.1 The vertical in-plane compressive load supported by a pillar bulkhead is to be taken as:

$$LV_{PB} = -(S_{pb} B_{pb} P_{CD} + L_A + [F_{CD}]) \text{ kN}$$

where

P_{CD} = inertial deck design pressure, as appropriate, plus any other local loadings directly above the pillar, in kN/m^2, *see Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.2*

$[F_{CD}]$ = inertial load or loads, in kN, from items of equipment, etc. on the supported deck, assumed zero if there is none over. F_{CD} is defined in *Vol 1, Pt 7, Ch 2, 5.1 Deck structures (DK) 5.1.5*

L_A = appropriate portion of the load or loads, in kN, from pillar(s) or bulkhead(s) above, assumed zero if there is none over, may be taken as LV_{PI} for the supported pillar or LV_{PB} for the supported bulkhead

S_{pb}, B_{pb} is the effective deck area supported by the pillar bulkhead and can be taken as follows:

(a) For longitudinal pillar bulkheads, *see Figure 2.5.7 Loads supported by a pillar bulkhead*:

B_{pb} = mean spacing of longitudinal bulkheads, side shell or effectively supported longitudinal girders, in metres

S_{pb} = length of the pillar bulkhead between major transverse bulkheads or effectively supported transverse web frames or similar, in metres

(b) For transverse pillar bulkheads:

S_{pb} = mean spacing of transverse bulkheads or effectively supported transverse web frames or similar, in metres

B_{pb} = breadth of the pillar bulkhead between major longitudinal bulkheads or the side shell, in metres.

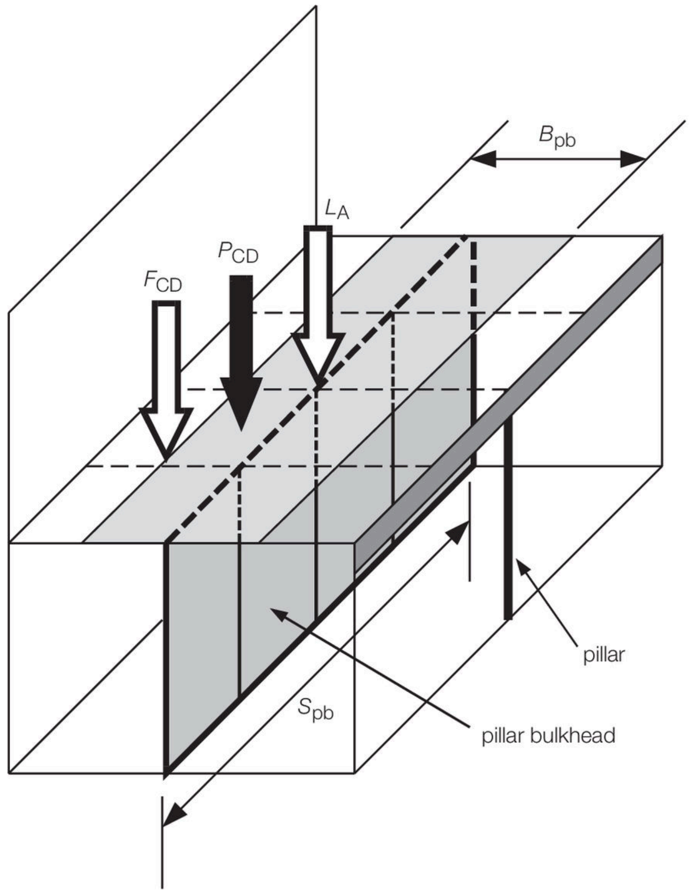


Figure 2.5.7 Loads supported by a pillar bulkhead

5.8.2 When any of the conditions below are satisfied then the pillar bulkhead load should be derived using direct calculation methods:

- where the structural arrangement is complex;
- where it is considered that the load in the pillar bulkhead will not be accurately represented by the above formulae, e.g. pillar bulkheads supporting decks in way of the ends of a long superstructure block;
- where the pillar bulkhead is not supported underneath by the double bottom or substantial structural members.

Section 1 Introduction

1.1 General

1.1.1 The Total Load Assessment, **TLA**, procedure is an optional procedure that is applied on a voluntary basis when an Owner or designer who seeks to increase confidence levels in the structural integrity of a ship. The **TLA** procedure is illustrated in *Figure 3.1.1 Overview of the Total Load Assessment, TLA Procedure*

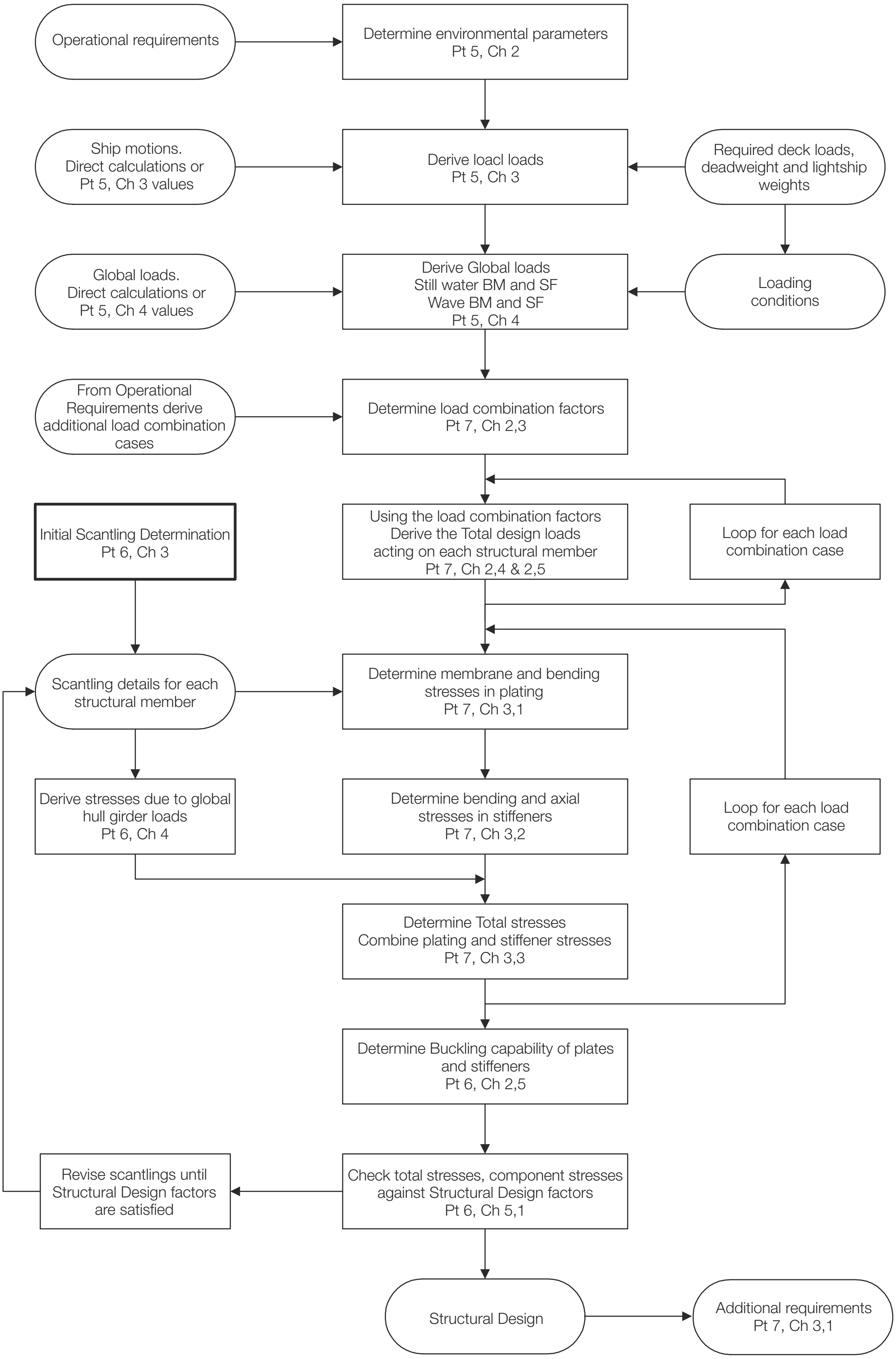


Figure 3.1.1 Overview of the Total Load Assessment, TLA Procedure

1.1.2 The **TLA** procedure is based on the following concepts:

(a) Derive the total design loads acting on each structural member.
(b) Derive the structural resistance of each structural member.
(c) Derive the load utilisation factors.
(d) Ensure the load utilisation factors are less than the required design factors.

1.1.3 This Chapter gives the simplified stress analysis methods to be used for the **TLA** procedure. Direct calculations or alternative proven methods of analysis which are more rigorous will be accepted.

1.1.4 The design loads for the **TLA** procedure are given in *Vol 1, Pt 7, Ch 2 Total Design Loads*, Total Design Loads.

1.1.5 The structural design factors are given in *Vol 1, Pt 7, Ch 3, 4 Structural design factors* and utilise the design criteria in *Vol 1, Pt 6, Ch 5 Structural Design Factors*

1.1.6 The simplified stress analysis techniques predict the total stresses acting in the structure as a consequence of the total loads. These techniques cover the assessment of stresses in the following:

- Primary structure.
- Primary/secondary plating systems.
- Grillage plating systems.

1.1.7 The resulting stresses are then checked against a set of design factors, which include stress, deflection and buckling requirements.

1.1.8 The **TLA** procedure is in addition to the normal Rule structural design approval requirements specified within *Vol 1, Pt 6, Ch 3 Scantling Determination*.

1.2 Structural design

1.2.1 The **TLA** procedure only forms part of the structural design process, **TLA** covers the structural design of the ship in the sea environment only. There are many other structural requirements as a consequence of other loads and good structural design practices that need to be incorporated. These include:

- bow flare impact and bottom slamming loads;
- ice requirements;
- design requirements to cover other strength issues, for example helicopter or vehicle decks;
- military requirements such as fragmentation protection;
- local impact loadings due to tugs, docks;
- supporting structure for machinery, cranes and lifting devices; and
- corrosion margins.

1.2.2 The structural design should clearly exhibit good structural continuity and smooth transition of scantlings between adjacent plating areas. In general, the **TLA** derived maximum scantlings for each structural member at any section within $0,3L_R$ to $0,7L_R$ are to be maintained over the central region.

■ *Section 2* Structural resistance

2.1 Assessment of stresses in structural components

2.1.1 The equations and methods given below are to be used to derive the stresses acting within plating and within stiffeners and beams.

2.1.2 These equations are valid for plating and beams subjected to lateral, or normal, pressure or point loads, i.e. local design considerations.

2.1.3 The stresses in plating and beams subjected to hull girder loads are to be derived in accordance with the methods given in *Vol 1, Pt 6, Ch 4 Hull Girder Strength*

2.2 Stresses in plating

2.2.1 The loads acting on a plate panel and its dimensions are illustrated in *Figure 3.2.1 Membrane stress system for plating*

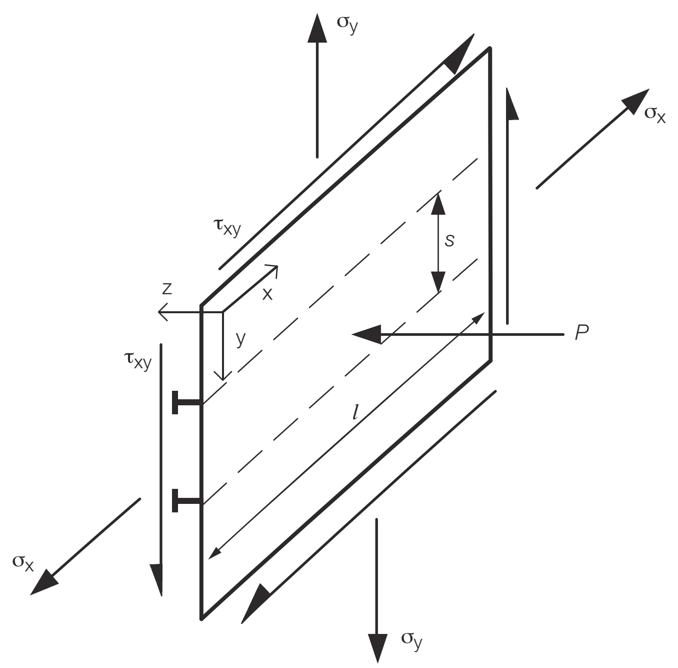


Figure 3.2.1 Membrane stress system for plating

2.2.2 The bending stress in a plate panel between stiffeners due to a uniform lateral pressure is to be calculated as follows:

$$\sigma_b = p\left(\frac{22,4_s\,\gamma\;\beta}{1000 t_p}\right) \mathrm{N/mm}^2$$

where

p = lateral pressure, in kN/m^2

t_p = thickness of plating, in mm

s = spacing of secondary stiffeners, in mm

l = length of the plate panel, in metres

γ = convex curvature correction, *see Vol 1, Pt 6, Ch 2, 2.4 Convex curvature correction*

β = aspect ratio correction, *see Vol 1, Pt 6, Ch 2, 2.5 Aspect ratio correction*

Note: The plate bending stresses are to be based on the actual stiffener spacing.

2.2.3 The direct stress in a plate panel subjected to membrane or in-plane loading is to be calculated as follows:

$$\sigma_x = \frac{10L}{A}\ \mathrm{N/mm}^2$$

where

L = in-plane load on the panel of plating, in kN

A = area normal to the load, L, in cm^2, ignoring secondary stiffeners which are not continuous but may include deep beams.

2.2.4 The shear stress in a plate panel is to be calculated as follows:

$$\tau_{\text{xy}} = \frac{10Q}{A}\ \text{N/mm}^2$$

where

Q = shear force acting on the panel of plating

A = cross-sectional area of the panel in the direction of the shear force, in cm^2

= $t_{\text{p}}\, b_{\text{v}}$ or $t_{\text{p}}\, b_{\text{t}}$

b_{t} and b_{v} are the total breadth of the plate panel over which the shear force acts.

2.3 Stresses in secondary and primary member stiffeners

2.3.1 The bending stresses, deflection and shear stress in stiffeners or beams due to lateral pressure loading or point loads are to be derived as given below.

2.3.2 The stresses in the stiffener flange, σ_{sf}, and the attached plating to the stiffener, σ_{sp}, due to the applied load are illustrated in *Figure 3.2.2 Bending stresses in stiffener beam* and may be derived using the formulae given below.

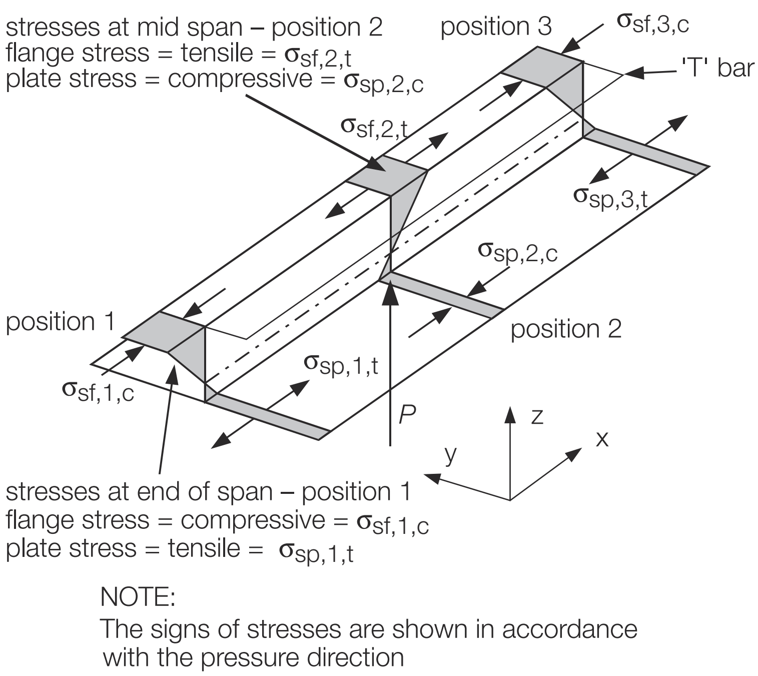


Figure 3.2.2 Bending stresses in stiffener beam

2.3.3 **Bending stresses**

Bending stress due to a lateral pressure load

$$\sigma_{\text{sf, j}} = +\frac{F_{\text{Zj}}\, p\, s_{\text{p}}\, l_{\text{e}}^{\,2}}{Z_{\text{f}}}\ \text{N/mm}^2$$

$$\sigma_{\mathrm{sp,j}} = -\frac{F_{\mathrm{Zj}} p\, s_{\mathrm{p}}\, l_{\mathrm{e}}^{2}}{Z_{\mathrm{p}}}\ \mathrm{N/mm^2}$$

Bending stress due to a point load or force

$$\sigma_{\mathrm{sf,j}} = +\frac{10^3 F_{\mathrm{Zj}} F\, l_{\mathrm{e}}}{Z_{\mathrm{f}}}\ \mathrm{N/mm^2}$$

$$\sigma_{\mathrm{sp,j}} = -\frac{10^3 F_{\mathrm{Zj}} F\, l_{e}}{Z_{\mathrm{p}}}\ \mathrm{N/mm^2}$$

Bending stress due to an applied end deflection

$$\sigma_{\mathrm{sf,j}} = +\frac{F_{\mathrm{Zj}}\ \delta\, E\, I}{10^5 l_{\mathrm{e}}^{2} Z_{\mathrm{P}}}\ \mathrm{N/mm^2}$$

$$\sigma_{\mathrm{sp,j}} = -\frac{F_{\mathrm{Zj}}\ \delta\, E\, I}{10^5 l_{\mathrm{e}}^{2} Z_{\mathrm{f}}}\ \mathrm{N/mm^2}$$

2.3.4 **Beam deflection**

Deflection in beam due to a lateral pressure load

$$\delta_{\mathrm{s,j}} = \frac{10^5 F_{\mathrm{Ij}}\, p\, s_{\mathrm{p}} l_{\mathrm{e}}^{4}}{E\, I}\ \mathrm{mm}$$

Deflection in beam due to point load

$$\delta_{\mathrm{s,j}} = \frac{10^8 F_{\mathrm{Ij}} F l_{\mathrm{e}}^{3}}{E\, I}\ \mathrm{mm}$$

2.3.5 **Shear stresses**

Shear stress in beam due to a lateral pressure load

$$\tau_{\mathrm{s,j}} = \frac{F_{\mathrm{Aj}} p s_{\mathrm{p}} l_{\mathrm{e}}}{100 A_{\mathrm{w}}}\ \mathrm{N/mm^2}$$

Shear stress in beam due to a point load

$$\tau_{\mathrm{s,j}} = \frac{10\, F_{Aj} F}{A_{\mathrm{w}}}\ \mathrm{N/mm^2}$$

Shear stress in beam due to an applied end deflection

$$\tau_{\mathrm{s,j}} = \frac{F_{\mathrm{Aj}} EI\ \delta}{10 l_{\mathrm{e}}^{3} A_{\mathrm{w}}}\ \mathrm{N/mm^2}$$

where

j = position along stiffener beam, where *j* = 1, 2 or 3, *see Table 2.2.1 Section modulus, inertia and web area coefficients for different load models* and *Figure 3.2.2 Bending stresses in stiffener beam*

Φ_{Zj}, Φ_{Ij} and Φ_{Aj} = are the section modulus inertia and shear web area coefficients dependent on the loading model assumption, *see Table 2.2.1 Section modulus, inertia and web area coefficients for different load models*, and the position along the stiffener beam

p = lateral pressure, in kN/m^2

F = applied force, in kN

δ = applied deflection, in mm

l_e = effective span length of the stiffener or primary member, in metres, *see Vol 1, Pt 6, Ch 2, 2.6 Determination of span length*

s_p is the stiffener spacing, in mm

s_p is to be taken as s for secondary stiffeners and 1000S for primary members, *see Vol 1, Pt 6, Ch 2, 1.3 Symbols and definitions 1.3.1*

Z_f and Z_p are the section moduli, in cm^3, of the stiffener including attached plating at the flange and attached plating respectively

I = section modulus, in cm^4

A_w = web area of stiffener, in cm^2

E = modulus of elasticity, in N/mm^2.

2.3.6 The suffixes ‘,*t*’ and ‘,*c*’ refer to the tensile or compressive values of bending stress in the stiffener which arise due to the stiffener end condition restraints, *see Figure 3.2.2 Bending stresses in stiffener beam*

■ *Section 3* Stress analysis model

3.1 General

3.1.1 The stress analysis model given in this Section is to be applied to the total design loads determined in accordance with *Vol 1, Pt 7, Ch 2 Total Design Loads*.

3.1.2 The stresses, deflections and other values are to be determined for all load cases and all the design load combinations specified in *Vol 1, Pt 7, Ch 2, 3 Design load combinations*

3.2 Stress determination in primary members

3.2.1 Primary members are major structural members and provide support to decks, major equipment, etc. and also control the cross-sectional and longitudinal shape between decks, side shell and bulkheads. The major primary members are listed in the paragraphs below.

3.2.2 The following structural items are classed as longitudinal primary members:

- Double bottom girders with attached bottom shell and inner bottom plating.
- Single bottom girders with attached bottom shell plating.
- Deck girders.
- Longitudinal stringers with attached side shell or longitudinal bulkhead plating.
- Horizontal diaphragms with attached side shell and inner skin plating.

3.2.3 The following structural items are classed as vertical primary members:

- Deep web frames supporting the side shell or bulkheads including attached plating.
- Double skin web frames including the attached side shell and inner skin plating.
- Deep vertical bulkhead stiffeners.

3.2.4 The following structural items are classed as transverse primary members:

- Double bottom floors with bottom shell and inner bottom plating.
- Single bottom floors with bottom shell plating.
- Deep deck or transverse beams with attached deck plating.
- Double skin deck beam with attached upper and lower deck plating.
- Transverse bulkhead stringers with attached bulkhead plating.

3.2.5 Primary members support the secondary members and can be considered to act independently of the secondary members. They need to be considered as a large beam supporting local loads with the global and local membrane stresses in the attached plating.

3.2.6 A typical primary member will consist of:

- Primary attached plating, e.g. bottom shell providing local bending capability.
- Web plate, providing shear capability.
- Upper flange or plating for double skin construction providing local bending capability.

The stresses in the attached plating and flange are to be derived in accordance with the requirements of this Section. The stresses in the web plating are to be determined in accordance with *Vol 1, Pt 7, Ch 3, 3.3 Stress determination in primary/secondary systems*, or *Vol 1, Pt 7, Ch 3, 3.4 Stress determination in grillage systems* if it is of grillage construction.

3.2.7 The stresses in primary members are to be derived using the recommended equations and stiffener end conditions given in *Table 3.3.1 Stress determination in primary members* The stress components used in deriving the primary member stresses are given below.

Table 3.3.1 Stress determination in primary members

Stress direction	Stress equation	Stiffener end condition	Notes
Longitudinal primary members			
σ_x	$\sigma_x = \sigma_{hg} + \sigma_{xb}$ N/mm^2	Built in	Applicable to the flange and the attached plating
σ_y	$\sigma_y = \sigma_{yg}$ N/mm^2 (attached to deck plating) $\sigma_y = \sigma_{xv}$ N/mm^2 (attached to side shell or long bhd plating)	N.A.	Only applicable to the attached plating
τ_{xy}	τ_{xy} is to be taken as the shear stress for the attached plating, *see Vol 1, Pt 7, Ch 3, 3.3 Stress determination in primary/secondary systems* or *Vol 1, Pt 7, Ch 3, 3.4 Stress determination in grillage systems*	—	Only applicable to the attached plating
Transverse primary members			
σ_x	$\sigma_x = \sigma_{yg} + \sigma_{xb}$ N/mm^2	Built in	Applicable to the flange and the attached plating
σ_y	$\sigma_y = \sigma_{hg}$ N/mm^2 (attached to deck plating) $\sigma_y = \sigma_{xv}$ N/mm^2 (attached to transverse bulkhead plating	N.A.	Only applicable to the attached plating
τ_{xy}	τ_{xy} is to be taken as the shear stress for the attached plating, *see Vol 1, Pt 7, Ch 3, 3.3 Stress determination in primary/secondary systems* or *Vol 1, Pt 7, Ch 3, 3.4 Stress determination in grillage systems*	—	Only applicable to the attached plating
Vertical primary members			
σ_x	$\sigma_x = \sigma_{xv} + \sigma_{xb}$ N/mm^2	Built in	Applicable to the flange and the attached plating
σ_y	$\sigma_y = \sigma_{hg}$ N/mm^2 (attached to side shell or long bhd plating) $\sigma_y = \sigma_{yg}$ N/mm^2 (attached to transverse bulkhead plating)	N.A.	Only applicable to the attached plating

τ_{xy}	τ_{xy} is to be taken as the shear stress for the attached plating, *see Vol 1, Pt 7, Ch 3, 3.3 Stress determination in primary/secondary systems* or *Vol 1, Pt 7, Ch 3, 3.4 Stress determination in grillage systems*	—	Only applicable to the attached plating

Symbols

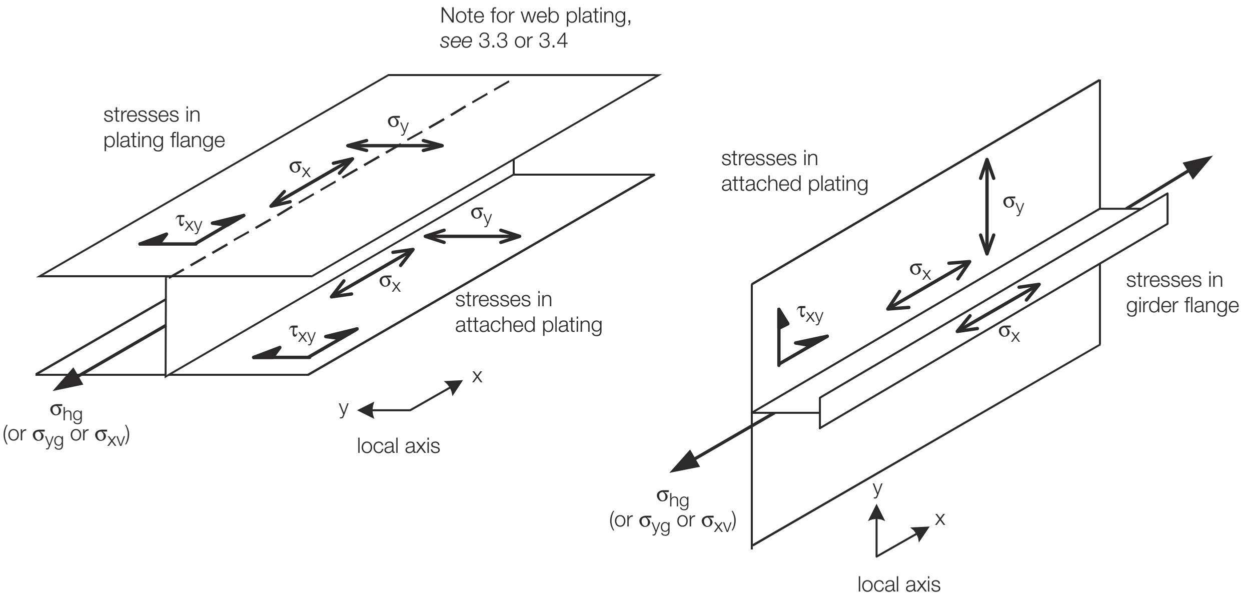
σ_x is along the span of the primary member

σ_{hg}, σ_{yg} and σ_{xv} are given in *Vol 1, Pt 7, Ch 3, 3.2 Stress determination in primary members 3.2.10*

σ_y is in the normal direction to the span in the attached plating

σ_{xb} is given in *Vol 1, Pt 7, Ch 3, 3.2 Stress determination in primary members 3.2.12*

τ_{xy} is only applicable to the attached plating



3.2.8 When it is considered that a different combination of stresses is likely to produce higher stresses, then this combination should be considered.

3.2.9 In general, a primary member will be subject to the following loads:

- In-plane or axial loading as a consequence hull girder loads, transverse loading due to side shell pressure loads or vertical support loads.
- Bending loads due to the member supporting out of plane external and internal pressures and equipment or cargo loadings.

3.2.10 The in-plane or axial loading in the primary member attached plating and flanges is to be taken as the membrane stress derived in accordance with the following:

(a) For longitudinally effective primary members:

σ_{hg} is the longitudinal stress due to hull girder bending

$$\sigma_{\text{hg}} = \frac{Z_{\text{na}} M_{\text{D}}}{1000 I_{\text{hg}}} \text{ N/mm}^2$$

(b) For primary members in the transverse direction:

σ_{yg} is the membrane stress due to a global load of *LT*

$$\sigma_{\text{yg}} = \frac{10\, LT}{A} \text{ N/mm}^2$$

(c) For primary members in the vertical direction:

σ_{xv} is the membrane stress due to a vertical load of *LV*

$$\sigma_{xv} = \frac{10\,LV}{A}\ \mathrm{N/mm^2}$$

where

M_D = design hull girder bending moment given in *Vol 1, Pt 7, Ch 2, 3 Design load combinations*

z_{na} = vertical distance above the neutral axis of the structural member under consideration, in metres

I_{hg} = the section inertia at the longitudinal position under consideration, *see Vol 1, Pt 6, Ch 4, 2.3 Shear strength*, in m^4

A = is the total area, in cm^2, of the primary member including the full breadth of attached plating

LT and *LV* are defined in *Vol 1, Pt 7, Ch 2, 2.1 Nomenclature 2.1.1*.

3.2.11 The out of plane bending loads to be applied to the primary member are specified in *Vol 1, Pt 7, Ch 2 Total Design Loads*. For example, the out of plane bending load for a double bottom girder is specified in *Vol 1, Pt 7, Ch 2, 4.6 Bottom longitudinal girders (BG) 4.6.7*. In this case the pressure components are to be uniformly distributed over the double bottom girder beam with the point loads applied as individual forces.

3.2.12 The stresses in the flange and attached plating due to bending of the primary member are to be derived as follows:

σ_{xb} = is the stress in the plating due to bending of the primary member beam/plate combination under lateral pressure loading or lateral inertial loads

σ_{xb} = is to be taken as the negative value of σ_{sp}, i.e. $\sigma_{sp,c}$, when the primary member axial stress is negative, similarly the positive value of σ_{sp}, i.e. $\sigma_{sp,t}$, is to be taken when is the axial stress positive

When appropriate the σ_{xb} value is to be the summation of stresses as result of inertial pressures and inertial point loads

$\sigma_{sp,c}$ and $\sigma_{sp,t}$ = are the maximum compressive and tensile stresses in the attached plating of the primary member and are to be derived using the bending stress equations in *Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.3*, *see also Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.6*

3.2.13 The section modulus of the primary member with regard to local bending properties is to be derived in accordance with *Vol 1, Pt 6, Ch 2, 2.3 Section properties* with effective breadths of attached plating as given by *Vol 1, Pt 6, Ch 2, 2.2 Effective width of attached plating, be*.

3.2.14 The total equivalent stress or von Mises stress, σ_{vm}, is to be derived using the following formula:

$$\sigma_{vm} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_y \sigma_x + 3\tau_{xy}^2}\ \mathrm{N/mm^2}$$

3.3 Stress determination in primary/secondary systems

3.3.1 The primary members support the secondary members. The secondary stiffeners transfer the lateral loads into the primary members.

3.3.2 An example of a primary/secondary plating and stiffener system is as follows: a longitudinal spacing of 600 mm and a transverse spacing of 2000 mm with the transverse stiffeners having a section inertia value of five times the secondary longitudinal stiffeners.

3.3.3 In a primary/secondary system it is normally sufficient to consider the secondary stiffeners as acting independently of the primary stiffeners. Hence the total stress analysis can ignore the effects of bending of the primary members.

3.3.4 The total stress analysis can be based on the plating between the primary transverse members and need only consider plating membrane stresses and bending stresses in secondary members.

3.3.5 The stresses in the plating of a primary/secondary plating system are to be derived using the recommended equations and stiffener end conditions given in *Table 3.3.2 Stress determination in longitudinal plating of primary/secondary systems, e.g., decks and longitudinal bulkheads* and *Table 3.3.3 Stress determination in transverse plating of primary/secondary systems, e.g.,*

transverse bulkheads The stresses in the flanges of panel stiffeners are given in *Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.6* using the conditions given in *Vol 1, Pt 7, Ch 3, 3.2 Stress determination in primary members 3.2.3* and *Vol 1, Pt 7, Ch 3, 3.3 Stress determination in primary/secondary systems 3.3.3* The stresses and nomenclature are shown in *Figure 3.3.1 Definition of stresses in a primary/secondary stiffened panel*

Table 3.3.2 Stress determination in longitudinal plating of primary/secondary systems, e.g., decks and longitudinal bulkheads

Stress direction	Stress equation		Stiffener end condition
	Plating	Stiffener flange	
Method AA Longitudinal secondary stiffeners			
σ_x	**Equation A** $\sigma_x = \sigma_{xg} + \sigma_{xb}$ N/mm^2	σ_{sx}, *see Vol 1, Pt 7, Ch 3, 3.11 Derivation of total stresses in stiffener flanges*	Built in
σ_y	**Equation D** $\sigma_y = \sigma_{yg}$ N/mm^2	N.A.	N.A.
τ_{xy}	**Equation E** $\tau_{xy} = \tau_{hg} + \frac{QT}{t_b b_T} + \frac{QV}{t_b b_V}$ N/mm^2	δ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.4* τ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.5*	
Method BB Longitudinal secondary stiffeners adjacent to bulkhead			
σ_x	**Equation A** $\sigma_x = \sigma_{xg} + \sigma_{xb}$ N/mm^2		Edge end built in. Other end free to deflect,no rotation, *see* Note 2
σ_y	**Equation D** $\sigma_y = \sigma_{yg}$ N/mm^2	N.A.	N.A.
τ_{xy}	**Equation E** $\tau_{xy} = \tau_{hg} + \frac{QT}{t_b b_T} + \frac{QV}{t_b b_V}$ N/mm^2	δ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.4* τ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.5*	
Method CC Transverse secondary stiffeners			
σ_x	**Equation B** $\sigma_x = \sigma_{xg}$ N/mm^2	N.A.	N.A.
σ_y	**Equation C** $\sigma_y = \sigma_{yg} + \sigma_{yb}$N/mm^2	σ_{sx}, *see Vol 1, Pt 7, Ch 3, 3.11 Derivation of total stresses in stiffener flanges*	Built in
τ_{xy}	**Equation E** $\tau_{xy} = \tau_{hg} + \frac{QT}{t_b b_T} + \frac{QV}{t_b b_V}$ N/mm^2	δ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.4* τ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.5*	

Note 1. The parameters for Equations A to E are given in *Vol 1, Pt 7, Ch 3, 3.5 Derivation of the combined longitudinal stress on panels subjected to hull girder bending* **Note** 2. Alternatively the deflection from the transverse member over its full span, excluding the support from longitudinal stiffeners, may be applied.

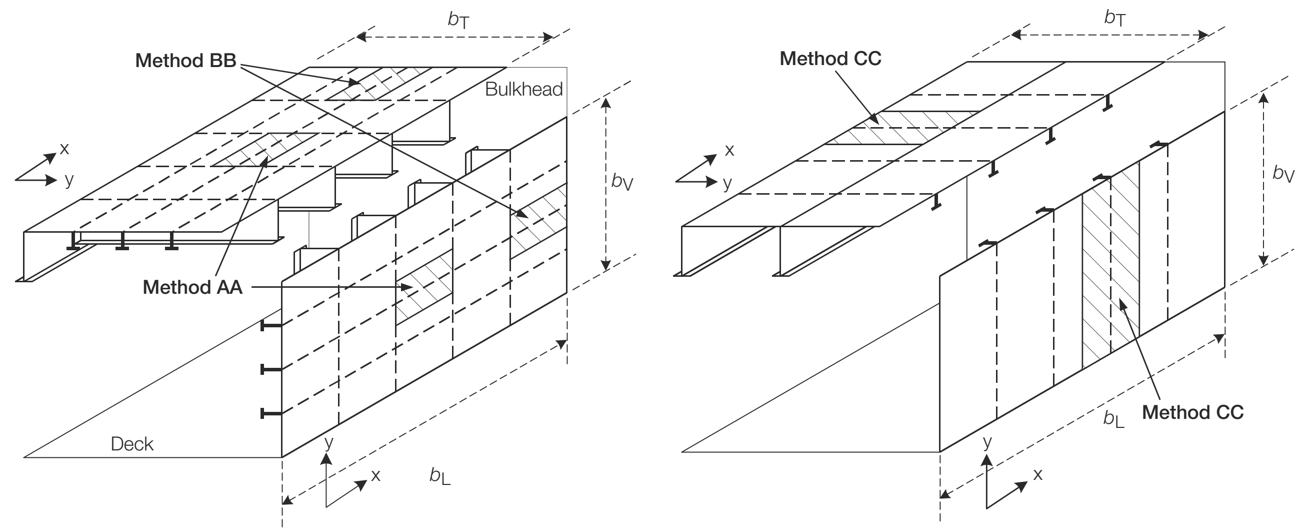
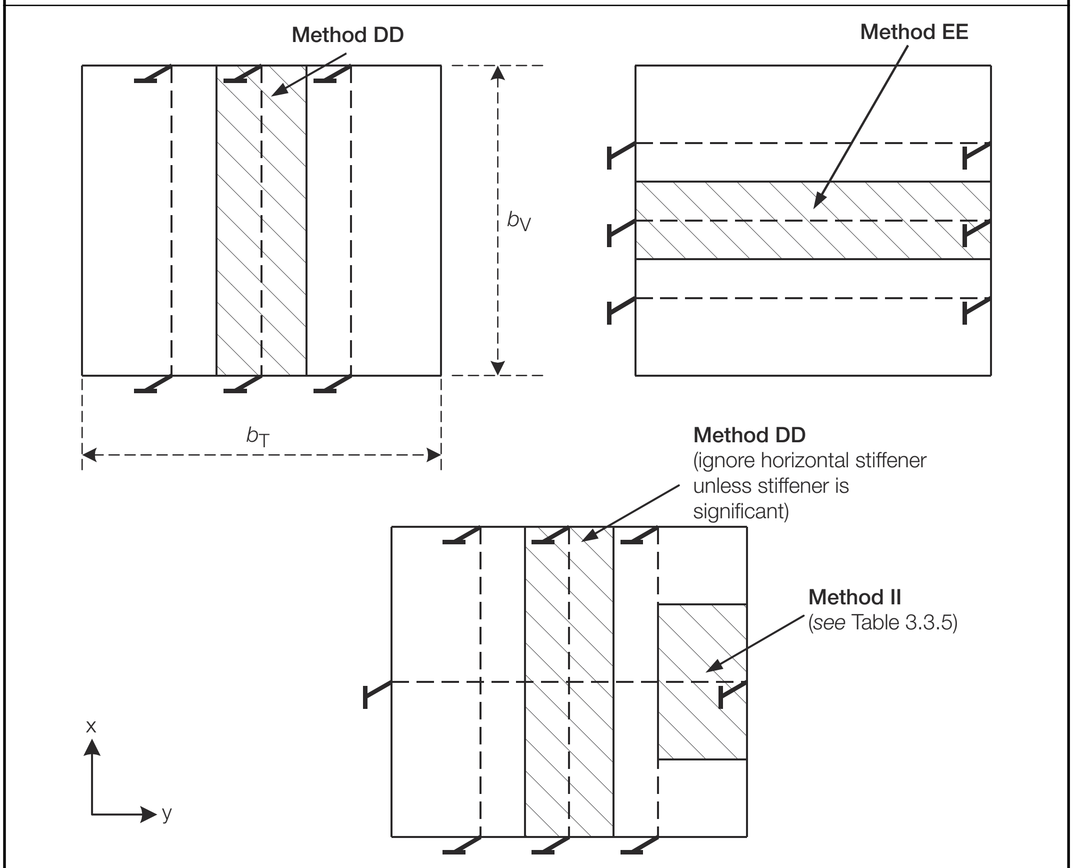


Table 3.3.3 Stress determination in transverse plating of primary/secondary systems, e.g., transverse bulkheads

Stress direction	Stress equation		Stiffener end condition
	Plating	Stiffener flange	
Method DD Vertical secondary stiffeners			
σ_x	**Equation H** $\sigma_x = \sigma_{xg} + \sigma_{xb}$ N/mm^2	σ_{sx}, *see Vol 1, Pt 7, Ch 3, 3.11 Derivation of total stresses in stiffener flanges*	N.A.
σ_y	**Equation G** $\sigma_y = \sigma_{yg}$ N/mm^2	N.A.	Built in
τ_{xy}	**Equation J** $\tau_{xy} = \tau_{xy} + \frac{QT}{t_b b_T} + \frac{QV}{t_b b_V}$ N/mm^2	δ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.4* τ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.5*	
Method EE Horizontal secondary stiffeners			
σ_x	**Equation I** $\sigma_x = \sigma_{xv}$ N/mm^2	N.A.	N.A.
σ_y	**Equation F** $\sigma_y = \sigma_{yg} + \sigma_{yb}$ N/mm^2	σ_{sx}, *see Vol 1, Pt 7, Ch 3, 3.11 Derivation of total stresses in stiffener flanges*	Built in

τ_{xy}	**Equation J** $\tau_{xy} = \tau_{xy} + \frac{QT}{t_b b_T} + \frac{QV}{t_b b_V} \text{N/mm}^2$	δ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.4* τ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.5*	

Note The parameters for Equations F to J are given in *Vol 1, Pt 7, Ch 3, 3.8 Derivation of the combined transverse stress acting on transversely orientated panels* to *Vol 1, Pt 7, Ch 3, 3.10 Derivation of the total shear stress on transversely orientated panels*.



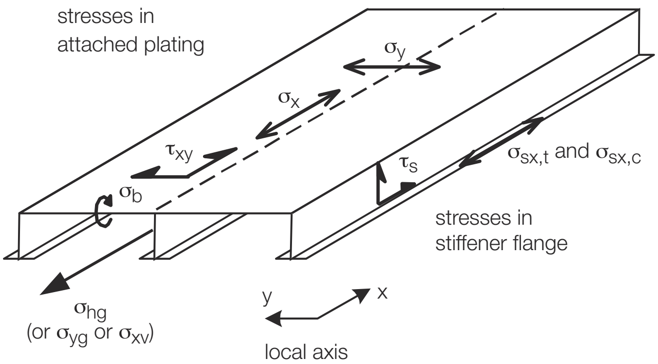


Figure 3.3.1 Definition of stresses in a primary/secondary stiffened panel

3.3.6 When it is considered that a different combination of stresses is likely to produce higher stresses, then this combination should be considered.

3.3.7 Buckling of plating is to be assessed using the in-plane membrane stresses only. The membrane stresses are to be derived as follows:

σ_x using Equation B

σ_y using Equation D

τ_{xy} using Equation E

where

Equations B, D and E are defined in *Table 3.3.2 Stress determination in longitudinal plating of primary/secondary systems, e.g., decks and longitudinal bulkheads*.

3.4 Stress determination in grillage systems

3.4.1 A grillage system of plating and stiffeners is one where the bending stiffness of the orthogonal stiffeners are similar in magnitude and the orthogonal stiffeners work together to support the applied loads. The grillage system is in turn supported by primary structural items such as deep girders, deep transverse beams or bulkheads.

3.4.2 An example of a grillage system is as follows: plating supported by a longitudinal spacing of 600 mm and a transverse spacing of 1500 mm with the transverse stiffeners having an section inertia value of 1,5 times the longitudinal stiffeners.

3.4.3 Normally it is necessary to use direct calculations to evaluate the stresses within a grillage plating system. However, it may be sufficient to consider the stiffeners perpendicular to an edge of the grillage panel as acting independently of the grillage system. *See Table 3.3.4 Stress determination in longitudinal plating of grillage systems, e.g., decks and longitudinal bulkheads* and Methods FF and GG in the attached figure, also Methods II and JJ in *Table 3.3.5 Stress determination in transverse plating of grillage systems, e.g., transverse bulkheads.*.

Table 3.3.4 Stress determination in longitudinal plating of grillage systems, e.g., decks and longitudinal bulkheads

Stress direction	Stress equation		Stiffener end condition
	Plating	Stiffener flange	
Method FF At the fore and aft edges of a grillage panel			
σ_x	**Equation A** $\sigma_x = \sigma_{xg} + \sigma_{xb}$ N/mm^2	σ_{sx}, *see Vol 1, Pt 7, Ch 3, 3.1 General 3.1.1*	Edge end built in. Other end free to deflect, no rotation, *see* Note 2
σ_y	**Equation D** $\sigma_y = \sigma_{yg}$ N/mm^2	N.A.	N.A.
τ_{xy}	**Equation E** $\tau_{xy} = \tau_{hg} + \frac{QT}{t_b b_T} + \frac{QV}{t_b b_V}$ N/mm^2	δ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.4* τ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.5*	
Method GG At the port and starboard edges of a grillage panel			
σ_x	**Equation B** $\sigma_x = \sigma_{xg}$ N/mm^2	N.A.	N.A.
σ_y	**Equation C** $\sigma_y = \sigma_{yg} + \sigma_{yb}$ N/mm^2	σ_{sx}, *see Vol 1, Pt 7, Ch 3, 3.11 Derivation of total stresses in stiffener flanges*	Edge end built in. Other end free to deflect, no rotation, *see* Note 3

τ_{xy}	**Equation E** $\tau_{xy} = \tau_{hg} + \frac{QT}{t_b b_T} + \frac{QV}{t_b b_V} \text{N/mm}^2$	δ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.4* τ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.5*	
Method HH At the centre of a grillage panel			
σ_x	**Equation A** $\sigma_x = \sigma_{xg} + \sigma_{xb}$ N/mm^2	σ_{sx}, *see Vol 1, Pt 7, Ch 3, 3.11 Derivation of total stresses in stiffener flanges*	Built in
σ_y	**Equation C** $\sigma_y = \sigma_{yg} + \sigma_{yb}$N/mm^2	σ_{sx}, *see Vol 1, Pt 7, Ch 3, 3.11 Derivation of total stresses in stiffener flanges*	Built in
τ_{xy}	**Equation E** $\tau_{xy} = \tau_{hg} + \frac{QT}{t_b b_T} + \frac{QV}{t_b b_V} \text{N/mm}^2$	δ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.4* τ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.5*	
Note 1. The parameters for Equations A to E are given in *Vol 1, Pt 7, Ch 3, 3.5 Derivation of the combined longitudinal stress on panels subjected to hull girder bending* to *Vol 1, Pt 7, Ch 3, 3.7 Derivation of the total shear stress*. Note 2. Alternatively the deflection from the longitudinal member over its full span, excluding the support from transverse stiffeners, may be applied. Note 3. Alternatively the deflection from the transverse member over its full span, excluding the support from longitudinal stiffeners, may be applied.			

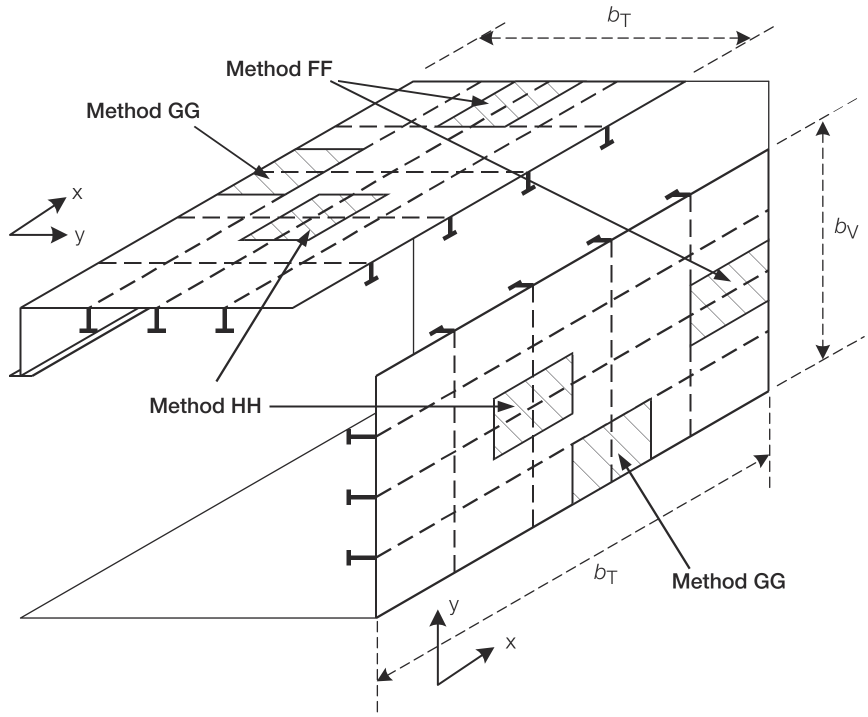


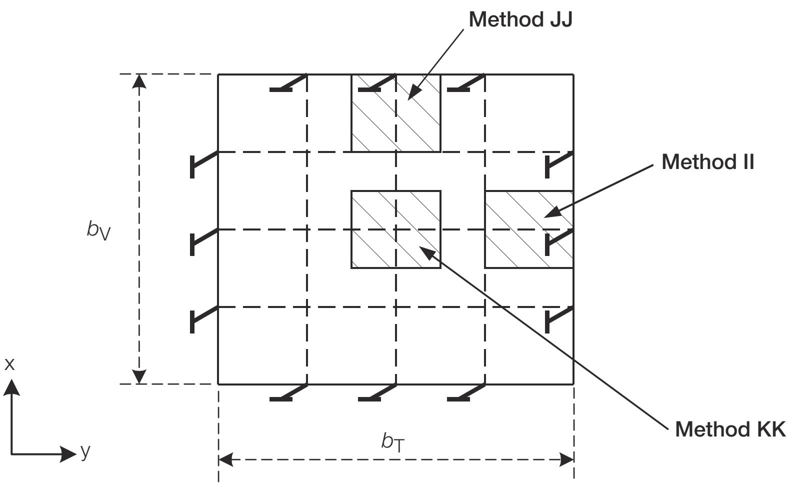
Table 3.3.5 Stress determination in transverse plating of grillage systems, e.g., transverse bulkheads.

Stress direction	Stress equation		Stiffener end condition
	Plating	Stiffener flange	
Method II Horizontal stiffeners at the port and starboard edges of a grillage panel			
σ_x	**Equation I** $\sigma_x = \sigma_{xv}$ N/mm^2	N.A.	Edge end Built in. Other end free to deflect, no rotation, *see* Note 2
σ_y	**Equation F** $\sigma_y = \sigma_{yg} + \sigma_{yb}$ N/mm^2	σ_{sx}, *see Vol 1, Pt 7, Ch 3, 3.11 Derivation of total stresses in stiffener flanges*	N.A.
τ_{xy}	**Equation J** $\tau_{xy} = \tau_{xy} + \frac{QT}{t_b b_T} + \frac{QV}{t_b b_V}$ N/mm^2	δ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.4* τ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.5*	–
Method JJ Vertical stiffeners at the top and bottom edges of a grillage panel			
σ_x	**Equation H** $\sigma_x = \sigma_{xv} + \sigma_{xb}$ N/mm^2	σ_{sx}, *see Vol 1, Pt 7, Ch 3, 3.11 Derivation of total stresses in stiffener flanges*	N.A.
σ_y	**Equation G** $\sigma_y = \sigma_{yg}$ N/mm^2	N.A.	Edge end built in. Other end free to deflect, no rotation, *see* Note 3
τ_{xy}	**Equation J** $\tau_{xy} = \tau_{xy} + \frac{QT}{t_b b_T} + \frac{QV}{t_b b_V}$ N/mm^2	δ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.4* τ_s *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.5*	–
Method KK At the centre of a grillage panel			
σ_x	**Equation H** $\sigma_x = \sigma_{xv} + \sigma_{xb}$ N/mm^2	σ_{sx}, *see Vol 1, Pt 7, Ch 3, 3.11 Derivation of total stresses in stiffener flanges*	Built in
σ_y	**Equation F** $\sigma_y = \sigma_{yg} + \sigma_{yf} + \sigma_{yb}$ N/mm^2	σ_{sx}, *see Vol 1, Pt 7, Ch 3, 3.11 Derivation of total stresses in stiffener flanges*	Built in
τ_{xy}	**Equation J** $\tau_{xy} = \tau_{xy} + \frac{QT}{t_b b_T} + \frac{QV}{t_b b_V}$ N/mm^2	δ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.4* τ_s, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.5*	–

Note 1. The parameters for Equations F to J are given in *Vol 1, Pt 7, Ch 3, 3.8 Derivation of the combined transverse stress acting on transversely orientated panels* to *Vol 1, Pt 7, Ch 3, 3.10 Derivation of the total shear stress on transversely orientated panels*.

Note 2. Alternatively the deflection of the vertical member over its full span, excluding the support from horizontal stiffeners, may be applied instead of the free to deflect condition.

Note 3. Alternatively the deflection from the horizontal member over its full span, excluding the support from vertical stiffeners, may be applied instead of the free to deflect condition.



3.4.4 The bending stresses in the edge stiffeners may be evaluated on the basis of encastre at the edge of the grillage panel and no rotation and free to deflect at the intersection with the first orthogonal stiffener.

3.4.5 In this case, the total stress analysis is to be based on the membrane stress in the plating of the grillage panel and consider the bending stresses in the middle stiffener perpendicular to the edge of the panel.

3.4.6 It will be necessary to derive the total stress at the edge of the panel for each stiffener direction.

3.4.7 The total stress in the centre of the grillage panel should also be checked. In this case it is necessary to consider the stresses in the plate due to bending of the stiffener in each direction as well as the plating stresses due to membrane loads.

3.4.8 The stresses in the plating of a grillage plating system are to be derived using the recommended equations and stiffener end conditions given in *Table 3.3.4 Stress determination in longitudinal plating of grillage systems, e.g., decks and longitudinal bulkheads* and *Vol 1, Pt 7, Ch 3, 3.3 Stress determination in primary/secondary systems 3.3.5* The stresses in the flanges of the panel stiffener are given by *Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.6*, using the conditions given in *Table 3.3.4 Stress determination in longitudinal plating of grillage systems, e.g., decks and longitudinal bulkheads* and *Table 3.3.5 Stress determination in transverse plating of grillage systems, e.g., transverse bulkheads.*. The stresses are illustrated in *Figure 3.3.2 Definition of stresses in a grillage stiffened panel*

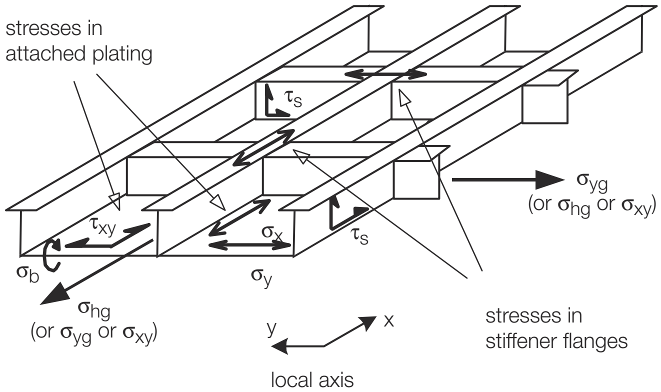


Figure 3.3.2 Definition of stresses in a grillage stiffened panel

3.4.9 When it is considered that a different combination of stresses is likely to produce higher stresses, then this combination should be considered.

3.4.10 Buckling of plating is to be assessed using the in-plane membrane stresses only. The membrane stresses are to be derived as follows:

σ_x using Equation B

σ_y using Equation D

τ_{xy} using Equation E

where

Equations B, D and E are defined in *Table 3.3.4 Stress determination in longitudinal plating of grillage systems, e.g., decks and longitudinal bulkheads*

3.5 Derivation of the combined longitudinal stress on panels subjected to hull girder bending

3.5.1 The longitudinal stresses in the plating and stiffener flanges for structural members subjected to hull girder bending loads as well as lateral loads are to be derived using the equations specified in this Section, *see Table 3.3.2 Stress determination in longitudinal plating of primary/secondary systems, e.g., decks and longitudinal bulkheads* and *Table 3.3.4 Stress determination in longitudinal plating of grillage systems, e.g., decks and longitudinal bulkheads*

3.5.2 **Equation A** is used for grillage systems or plating systems with the secondary stiffeners orientated in the longitudinal direction. For these systems, the stress in the plating/stiffener combination due to local bending needs to be considered in addition to the membrane stresses due to hull girder bending. The stress components in Equation A are given below.

3.5.3 **Equation B** is used for plating systems with the secondary stiffeners orientated in the transverse (or vertical) direction. For these systems only the longitudinal stress due to hull girder bending needs to be considered.

3.5.4 The longitudinal stress components associated with Equations A and B are given below:

$\boldsymbol{\sigma_{xg}}$ = is the longitudinal membrane stress due to hull girder bending

$$= \frac{Z_{\mathrm{na}} M_{\mathrm{D}}}{1000 I_{\mathrm{hg}}} \ \mathrm{N/mm^2}$$

$\boldsymbol{\sigma_{xb}}$ = is the stress in the plating due to bending of the longitudinal stiffener/plate combination under lateral pressure loading or lateral inertial loads

Normally σ_{xb} is to be taken as the negative value of σ_{sp}, i.e. $\sigma_{sp,c}$, when the hull girder bending stress σ_{xg} is negative, similarly the positive value of σ_{sp}, i.e. $\sigma_{sp,t}$, is to be taken when σ_{xg} is positive, *see Figure*

3.2.2 Bending stresses in stiffener beam However, there may be cases where it is necessary to consider the opposite situation

When appropriate, the σ_{xb} value is to be the summation of stresses as result of inertial pressures and inertial point loads

$\boldsymbol{\sigma}_{sp,c}$ and $\boldsymbol{\sigma}_{sp,t}$ = are the maximum compressive and tensile stresses in the plating of the stiffener/plate combination and are to be derived using the bending stress equations in *Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.3*, *see also Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.6*

M_D = design hull girder bending moment, in kNm given in *Vol 1, Pt 7, Ch 2, 3 Design load combinations*

z_{na} = vertical distance above the neutral axis of the structural member under consideration, in metres

I_{hg} = the section inertia at the longitudinal position under consideration, *see Vol 1, Pt 6, Ch 4, 2 Hull girder strength*, in m^4.

3.6 Derivation of the combined transverse stress acting on panels subjected to hull girder bending

3.6.1 The transverse stresses in the plating and stiffener flanges for structural members subjected to transverse loads as well as lateral loads are to be derived using the equations specified in this Section, *see Table 3.3.2 Stress determination in longitudinal plating of primary/secondary systems, e.g., decks and longitudinal bulkheads* and *Table 3.3.4 Stress determination in longitudinal plating of grillage systems, e.g., decks and longitudinal bulkheads*

3.6.2 **Equation C** is used for grillage systems or plating systems with the secondary stiffeners orientated in the transverse direction. For these systems, the stress in the plating/stiffener combination due to local bending needs to be considered in addition to membrane stresses due to global transverse loading. The stress components in Equation C are given below.

3.6.3 **Equation D** is used for plating systems with the secondary stiffeners orientated in the longitudinal direction. For these systems, only membrane stress due to global transverse loading needs to be considered.

3.6.4 The transverse stress components associated with equations C and D are given below:

$\boldsymbol{\sigma}_{yg}$ = is the membrane stress due to global transverse loading

$$= \frac{LT}{t_{\mathrm{p}} b_{\mathrm{L}}}\ \mathrm{N/mm^2}$$

$\boldsymbol{\sigma}_{yb}$ = is the stress in the plating due to bending of the longitudinal stiffener/plate combination under lateral pressure loading or lateral inertial loads

Normally, σ_{yb} is to be taken as the negative value of σ_{sp}, i.e. $\sigma_{sp,c}$, when the global transverse stress σ_{yg} is negative, similarly the positive value of σ_{sp}, i.e. $\sigma_{sp,t}$, is to be taken when σ_{yg} is positive, *see Figure 3.3.2 Definition of stresses in a grillage stiffened panel*. However, there may be cases where it is necessary to consider the opposite situation.

When appropriate, the σ_{yb} value is to be the summation of stresses as result of inertial pressures and inertial point loads

$\boldsymbol{\sigma}_{sp,c}$ and $\boldsymbol{\sigma}_{sp,t}$ = are the maximum compressive and tensile stresses in the plating of the stiffener/plate combination and are to be derived using the bending stress equations in *Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.3*, *see also Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.6*

LT = is the appropriate transverse design load, in kN, given in *Vol 1, Pt 7, Ch 2 Total Design Loads*, i.e. LT_{DK}, LT_{BS}, etc.

t_p = thickness of plating, in mm

b_L = breadth of plating, in metres, over which the load *LT* applies. Normally, this is the distance between decks or the height of the plating panel.

3.7 Derivation of the total shear stress

3.7.1 **Equation E** is used to derive the total shear stress in the plating for all plating systems.

3.7.2 The shear stress components associated with Equation E are given below:

|Q| = denotes the absolute value of parameter *Q*

τ_{hg} = $\dfrac{|Q_{\mathrm{D}}| A_{\mathrm{z}}}{I_{hg}\,\delta_{\mathrm{i}}}$ N/mm^2

Q_D = is global hull girder shear force, in kN. This will be zero for all transverse plating systems

Q_D = is given in *Vol 1, Pt 7, Ch 2 Total Design Loads*,*Vol 1, Pt 7, Ch 3 Total Load Assessment, TLA*

Q_T = local shear force due to local transverse loads, in kN, given in *Vol 1, Pt 7, Ch 2 Total Design Loads*, e.g. QT_{DK}, QT_{ST}

QV = local shear force due to local inertial forces, in kN, given in *Vol 1, Pt 7, Ch 2 Total Design Loads*, e.g. QV_{DG}, QV_{BG}

A_z, I_{hg} and δ_i are given in *Vol 1, Pt 6, Ch 4, 2.3 Shear strength 2.3.5*

b_V, b_T = total breadth over which the shear force acts, typically the height or breadth of the plating panel, in metres, *see Table 3.3.2 Stress determination in longitudinal plating of primary/secondary systems, e.g., decks and longitudinal bulkheads* or *Table 3.3.4 Stress determination in longitudinal plating of grillage systems, e.g., decks and longitudinal bulkheads*

NOTE

All shear force loads are to be assumed positive.

3.8 Derivation of the combined transverse stress acting on transversely orientated panels

3.8.1 The transverse stresses in the plating and stiffener flanges for structural members subjected to transverse loads as well as lateral loads are to be derived using the equations specified in this Section, *see Table 3.3.3 Stress determination in transverse plating of primary/secondary systems, e.g., transverse bulkheads* and *Table 3.3.5 Stress determination in transverse plating of grillage systems, e.g., transverse bulkheads.*

3.8.2 **Equation F** is used for grillage systems or plating systems with the secondary stiffeners orientated in the transverse direction.

3.8.3 **Equation G** is used for plating systems with the secondary stiffeners orientated in the vertical direction.

3.8.4 The transverse stress components associated with Equations F and G are given in *Vol 1, Pt 7, Ch 3, 3.6 Derivation of the combined transverse stress acting on panels subjected to hull girder bending 3.6.4*.

3.9 Derivation of the combined vertical stress acting on transversely orientated panels

3.9.1 The vertical stresses in the plating and stiffener flanges for structural members subjected to vertical loads as well as lateral loads are to be derived using the equations specified in this Section, *see Table 3.3.3 Stress determination in transverse plating of primary/secondary systems, e.g., transverse bulkheads* and *Vol 1, Pt 7, Ch 3, 3.3 Stress determination in primary/secondary systems 3.3.5*

3.9.2 **Equation H** is used for grillage systems or plating systems with the transverse secondary stiffeners orientated in the vertical direction.

3.9.3 **Equation I** is used for plating systems with the secondary stiffeners orientated in the transverse direction.

3.9.4 The vertical stress components associated with Equations H and I are given below:

σ_{xv} = is the membrane stress due to vertical loading

= $\dfrac{LV}{t_p b_T}$ N/mm^2

σ_{xb} = is the stress in the plating due to bending of the longitudinal stiffener/plate combination under lateral pressure loading or lateral inertial loads

Normally σ_{xb} is to be taken as the negative value of σ_{sp}, i.e. $\sigma_{sp,c}$, when the vertical stress σ_{xv} is negative, similarly the positive value of σ_{sp}, i.e. $\sigma_{sp,t}$, is to be taken when σ_{xv} is positive, *see Vol 1, Pt 7, Ch 3, 3.2 Stress determination in primary members 3.2.2*. However, there may be cases where it is necessary to consider the opposite situation

When appropriate, the σ_{xb} value is to be the summation of stresses as result of inertial pressures and inertial point loads

$\sigma_{sp,c}$ and $\sigma_{sp,t}$ = are the maximum compressive and tensile stresses in the plating of the stiffener/plate combination and are to be derived using the bending stress equations in *Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.3*, *see also Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.6*

where

LV = is the design load, in kN, given in *Vol 1, Pt 7, Ch 2 Total Design Loads*, e.g. LV_{SS}, LV_{BH}

t_p = thickness of plating, in mm

b_T = breadth of plating, in metres, over which the load LV applies. Normally, this is the distance between the side shell(s) or longitudinal bulkheads but it is to be reduced for the presence of large openings.

3.10 Derivation of the total shear stress on transversely orientated panels

3.10.1 **Equation J** is used to derive the total shear stress in any plating system which is not subjected to global hull girder shear force.

3.10.2 The shear stress components associated with Equation J are given below:

Q_T = local shear force due to local transverse loads, in kN, given in *Vol 1, Pt 7, Ch 2 Total Design Loads*, e.g. QT_{DK}, QT_{SF}, QT_{ST}

QV = local shear force due to local inertial forces, in kN, given in *Vol 1, Pt 7, Ch 2 Total Design Loads*, e.g. QV_{BM}, QV_{DG}, QV_{BG}, QV_{FL}

B_V, B_T = total breadth, in m, over which the shear force acts, *see Table 3.3.3 Stress determination in transverse plating of primary/secondary systems, e.g., transverse bulkheads* or *Vol 1, Pt 7, Ch 3, 3.3 Stress determination in primary/secondary systems 3.3.5*.

NOTE

All shear force loads are to be assumed positive.

3.11 Derivation of total stresses in stiffener flanges

3.11.1 The total compressive and tensile stresses in stiffener flanges, σ_{sx}, are given by the following:

$\sigma_{sx,c}$ = $\sigma_{ax} + \sigma_{sf,c}$ N/mm^2 (compressive)

$\sigma_{sx,t}$ = $\sigma_{ax} + \sigma_{sf,t}$ N/mm^2 (tensile)

where

σ_{ax} = is the axial stress in the stiffener at the combined stiffener plate neutral axis, this is normally to be taken as the membrane stress in the plating, i.e. σ_{xg}, σ_{yg} or σ_{xv} depending on the orientation of the stiffener, *see Vol 1, Pt 7, Ch 3, 3.5 Derivation of the combined longitudinal stress on panels subjected to hull girder bending 3.5.4*, *Vol 1, Pt 7, Ch 3, 3.6 Derivation of the combined transverse stress acting on panels subjected to hull girder bending 3.6.4* or *Vol 1, Pt 7, Ch 3, 3.9 Derivation of the combined vertical stress acting on transversely orientated panels 3.9.4*

$\sigma_{sf,t}$, $\sigma_{sf,c}$ = are the tensile and compressive bending stresses the stiffener flange, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.3* and *Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.6*, using the appropriate boundary conditions given in *Vol 1, Pt 7, Ch 3, 3 Stress analysis model*

3.11.2 These formulae may be applied to grillage and primary/secondary stiffened plating systems. The stresses in a stiffener beam subjected to more than one load may be derived by adding the stresses from each load component.

3.12 Derivation of total equivalent stress

3.12.1 The total equivalent stress or von Mises stress, σ_{vm}, is to be derived using the following formula:

$$\sigma_{vm} = \sqrt{\sigma_x^2 + \sigma_y^2 - \sigma_y \sigma_x + 3\tau_{xy}^2} \text{ N/mm}^2$$

Section 4
Structural design factors

4.1 General

4.1.1 This Section gives the allowable design criteria to be used to assess the structure for maximum and minimum stresses and other values derived in accordance with the **TLA** method.

4.1.2 The allowable design criteria are also to be used when direct calculation or similar methods are used as an alternative to the **TLA** stress analysis model in *Vol 1, Pt 7, Ch 3, 3 Stress analysis model*.

4.1.3 The allowable design criteria are applicable for all ships including NS1 ships.

4.2 Design criteria for the Total Load Assessment (TLA) approach

4.2.1 The stresses in the plating and stiffeners that have been derived using the **TLA** method are to be less than the allowable stresses and other design criteria given in this Section. For all areas of the structure, the modes of failures specified in *Table 3.4.1 Design criteria for plating* to *Table 3.4.4 Design criteria for primary members* are to be satisfied. *See also Vol 1, Pt 7, Ch 3, 4.3 Presentation of results* for presentation of results.

4.2.2 In order to satisfy the requirements, the ratio of the actual stress to the allowable stress or load utilisation factor is to be less than 1,0, similarly for the deflection and buckling utilisation factors. Hence

$\sigma/\sigma_a < 1,0$

$\lambda/\lambda_a < 1,0$

$\delta/\delta_a < 1,0$

where

σ = is the actual stress value

σ_a = is the allowable stress value, *see Vol 1, Pt 7, Ch 3, 4.2 Design criteria for the Total Load Assessment (TLA) approach 4.2.3*

λ = is the actual buckling factor of safety achieved

λ_a = is the allowable buckling factor of safety, *see Vol 1, Pt 7, Ch 3, 4.2 Design criteria for the Total Load Assessment (TLA) approach 4.2.4*

δ = is the actual deflection

δ_a = is the allowable deflection value, *see Vol 1, Pt 7, Ch 3, 4.2 Design criteria for the Total Load Assessment (TLA) approach 4.2.5*

4.2.3 The allowable stresses are to be derived using the following formulae:

- Direct or bending allowable stress

$\sigma_a = f_1 f_{hts} \sigma_o$ N/mm^2

- Shear allowable stress

$\tau_a = f_1 f_{hts} \tau_o$ N/mm^2

where

f_1 is taken from *Table 5.3.2 Allowable stress factors f 1* in Pt 6, Ch 5, as specified below:

- *Table 3.4.1 Design criteria for plating* for plating.
- *Table 3.4.2 Design criteria for stiffeners* for stiffeners.
- *Table 3.4.3 Design criteria for stiffened panels* for plate panels.
- *Table 3.4.4 Design criteria for primary members* for primary members.

f_{hts} = correction factor for high tensile steel, *see Vol 1, Pt 6, Ch 5, 1.3 Higher tensile steel*

σ_o = is the minimum yield stress

τ_o = is the minimum shear yield stress.

4.2.4 The buckling design safety factors are given in *Table 5.3.2 Allowable stress factors f 1* in Pt 6, Ch 5.3 and are to be used in conjunction with the buckling requirements specified in *Vol 1, Pt 6, Ch 2, 3 Buckling*. The required values of safety factors λ_σ and λ_τ are as specified by f_1 in *Vol 1, Pt 7, Ch 3, 4.2 Design criteria for the Total Load Assessment (TLA) approach 4.2.3*.

(a) $\lambda_a = f_1$

where

f_1 = is taken from *Table 5.3.2 Allowable stress factors f 1* in Pt 6, Ch 5.3 as specified in *Vol 1, Pt 7, Ch 3, 4.2 Design criteria for the Total Load Assessment (TLA) approach 4.2.3*

4.2.5 The limiting deflection requirements for stiffening members specified in *Table 3.4.1 Design criteria for plating* to *Table 3.4.4 Design criteria for primary members* are to be satisfied. The allowable deflection criteria are expressed as a deflection/span ratio and the actual deflection is to be less than the allowable deflection, δ_a, where δ_a is as follows:

$\delta_a = f_1 l_e$ mm

where

f_1 is taken from *Table 5.3.2 Allowable stress factors f 1* in Pt 6, Ch 5 as specified in *Vol 1, Pt 7, Ch 3, 4.2 Design criteria for the Total Load Assessment (TLA) approach 4.2.3*

l_e = effective span length, in metres.

4.2.6 The assessment of scantling requirements to satisfy the impact or slamming pressure loads for plating and stiffening is given in *Vol 1, Pt 6, Ch 3, 14 Strengthening for bottom slamming* and *Vol 1, Pt 6, Ch 3, 15 Strengthening for wave impact loads above waterline*.

Table 3.4.1 Design criteria for plating

Stress N/mm^2	Description	Design criteria	Factor f_1 *See* column in *Table 5.3.2 Allowable stress factors f 1* in Pt 6, Ch 5
	Stress criteria		
σ_b	Bending stress in plate due to lateral pressure, *see Vol 1, Pt 7, Ch 3, 2.2 Stresses in plating 2.2.2*	Local stress requirements	σ_b
σ_x	Longitudinal membrane stress in plate including the stresses due to stiffener bending, *see Vol 1, Pt 7, Ch 3, 3.3 Stress determination in primary/secondary systems* or *Vol 1, Pt 7, Ch 3, 3.4 Stress determination in grillage systems*	Hull girder bending requirements	σ_x
σ_y	Transverse (or vertical) membrane stress in plate, *see Vol 1, Pt 7, Ch 3, 3 Stress analysis model*	None	None
τ_{xy}	Shear stress due to global and local loads, *see Vol 1, Pt 7, Ch 3, 3 Stress analysis model*	Hull girder shear requirements	τ_{xy}
σ_{vm}	Combined total equivalent stress in plate, *see Vol 1, Pt 7, Ch 3, 3.12 Derivation of total equivalent stress*	Yield stress criterion	σ_{vm}
	Buckling criteria		
σ_{xg}, σ_{yg}, or σ_{xv}	Compressive membrane stress, *see Vol 1, Pt 7, Ch 3, 3.3 Stress determination in primary/ secondary systems* or *Vol 1, Pt 7, Ch 3, 3.4 Stress determination in grillage systems*	Uni-axial buckling, *see Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements*	λ_σ
τ_{xy}	Shear stress, *see Vol 1, Pt 7, Ch 3, 3 Stress analysis model*	Shear buckling, *see Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements*	λ_τ
σ_x, σ_y, τ_{xy}	Bi-axial and shear stress field, *see Vol 1, Pt 7, Ch 3, 3 Stress analysis model*	Bi-axial and shear buckling , *see Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements*	λ_σ and λ_τ

Table 3.4.2 Design criteria for stiffeners

Stress N/mm^2	Description	Design criteria		Factor f_1 *See* column in *Table 5.3.2 Allowable stress factors f 1* in Pt 6, Ch 5
	Stress criteria			
$\sigma_{sx,t}$	Maximum tensile (+ve) bending stress in flange of stiffener, *see Vol 1, Pt 7, Ch 3, 3.11 Derivation of total stresses in stiffener flanges*	Elastic stress criteria -	local loads only	σ_x
			hull girder and local loads	σ_{vm}

$\sigma_{sx,c}$	Maximum compressive (-ve) bending stress in flange of stiffener, *see Vol 1, Pt 7, Ch 3, 3.11 Derivation of total stresses in stiffener flanges*	Elastic stress criteria - local loads only Elastic stress criteria - hull girder and local loads	σ_x σ_{vm}
	Buckling criteria		
σ_{ax}	Overall axial stress, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.6*	Buckling control column, flange, web, torsional, tripping modes of buckling, *see Vol 1, Pt 6, Ch 2, 3.7 Secondary stiffening in direction of compression*	λ_σ
$\sigma_{sx,c}$	Maximum compressive (-ve) bending stress in flange of stiffener, *see Vol 1, Pt 7, Ch 3, 3.11 Derivation of total stresses in stiffener flanges*	Buckling of flange, *see Vol 1, Pt 6, Ch 2, 3.7 Secondary stiffening in direction of compression*	λ_σ
	Other criteria		
τ_s	Shear stress in web, *see* Tables *Table 3.3.2 Stress determination in longitudinal plating of primary/ secondary systems, e.g., decks and longitudinal bulkheads*, *Table 3.3.3 Stress determination in transverse plating of primary/secondary systems, e.g., transverse bulkheads*, *Table 3.3.4 Stress determination in longitudinal plating of grillage systems, e.g., decks and longitudinal bulkheads* and *Table 3.3.5 Stress determination in transverse plating of grillage systems, e.g., transverse bulkheads.*	Shear stress criteria for web area	τ_{xy}
δ_s	Deflection of stiffener due to lateral bending, *see Table 3.3.2 Stress determination in longitudinal plating of primary/secondary systems, e.g., decks and longitudinal bulkheads*, *Table 3.3.3 Stress determination in transverse plating of primary/secondary systems, e.g., transverse bulkheads*, *Table 3.3.4 Stress determination in longitudinal plating of grillage systems, e.g., decks and longitudinal bulkheads*, *Table 3.3.5 Stress determination in transverse plating of grillage systems, e.g., transverse bulkheads.*	Inertia/deflection criteria	f_δ

Table 3.4.3 Design criteria for stiffened panels

Stress N/mm^2	Description	Design criteria	Factor f_1 *See* column in *Table 5.3.2 Allowable stress factors f 1* in Pt 6, Ch 5
	Buckling criteria		
σ_{xg}, σ_{yg}, or σ_{xv}	Membrane stress	Overall panel buckling, *see Vol 1, Pt 6, Ch 2, 3.8 Secondary stiffening perpendicular to direction of compression*	λ_σ
τ_{xy}	Shear stress	Shear buckling of stiffened panels, *see Vol 1, Pt 6, Ch 2, 3.6 Shear buckling of stiffened panels*	λ_τ

	Other criteria		
δ_s	Deflection of panel due to lateral bending, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.4*	Inertia/deflection criteria	f_δ

Table 3.4.4 Design criteria for primary members

Stress N/mm^2	Description	Design criteria	Factor f_1 *See* column in *Table 5.3.2 Allowable stress factors f 1* in Pt 6, Ch 5
	Stress criteria		
	Web plating of primary member, *see Vol 1, Pt 7, Ch 3, 3.3 Stress determination in primary/secondary systems* or *Vol 1, Pt 7, Ch 3, 3.4 Stress determination in grillage systems*		
σ_b	Bending stress due to lateral pressure	Local stress requirements	σ_b
σ_x	Longitudinal membrane stress including the stresses due to secondary stiffener bending	Hull girder bending requirements	σ_x
σ_y	Transverse (or vertical) membrane stress including the stresses due to secondary stiffener bending	Local stress requirements	σ_y
τ_{xy}	Shear stress due to global and local loads	Shear stress requirements	τ_{xy}
σ_{vm}	Combined total equivalent stress	Yield stress criterion	σ_{vm}
	Flanges of primary member, *see Vol 1, Pt 7, Ch 3, 3.2 Stress determination in primary members*		
σ_x	Maximum tensile (+ve) bending stress in plate or flange	Elastic stress criteria	σ_{vm}
σ_x	Maximum compressive (-ve) bending stress in plate or flange	Elastic stress criteria	σ_{vm}
σ_{vm}	Combined total equivalent stress	Yield stress criterion	σ_{vm}
	Buckling criteria of primary member		
σ_{hg}, σ_{yg} or σ_{xv}	Compressive stress at neutral axis, excluding the stresses due to secondary stiffener bending	Buckling of primary girders, *see Vol 1, Pt 6, Ch 2, 3.9 Buckling of primary members*	λ_σ
τ_{xy}	Shear stress in web plating due to global and local loads	Shear buckling of girder webs, *see Vol 1, Pt 6, Ch 2, 3.10 Shear buckling of girder webs*	λ_τ
σ_x, σ_y, τ_{xy}	Bi-axial and shear stress field in web plating	Bi-axial and shear buckling, *see Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements*	λ_σ and λ_τ

σ_x	Maximum compressive (-ve) bending stress in plate or flange	Buckling of plate flange, *see Vol 1, Pt 6, Ch 2, 3.3 Plate panel buckling requirements* or buckling of flange, *see Vol 1, Pt 6, Ch 2, 3.7 Secondary stiffening in direction of compression*	λ_σ
	Other criteria		
τ_{xy}	Shear stress of girder web	Shear stress criteria for web area	τ_{xy}
δ_s	Deflection of girder due to lateral bending, *see Vol 1, Pt 7, Ch 3, 2.3 Stresses in secondary and primary member stiffeners 2.3.4*	Inertia/deflection criteria	f_δ

4.3 Presentation of results

4.3.1 It is recommended that the capability of the structure is represented by one of the following methods:

(a) Load utilisation factor, LUF, derived as follows:

$$\mathrm{LUF} = \frac{\mathrm{actualvalue}}{\mathrm{allowablevalue}}$$

e.g. the stress LUF = $\dfrac{\sigma}{\sigma_a}$

(b) Adequacy parameter, AP, defined as follows:

$$\mathrm{AP} = \frac{1 - \mathrm{LUF}}{1 + \mathrm{LUF}}$$

where

LUF is given above.

4.3.2 *Table 3.4.5 Adequacy parameter (AP)* shows a comparison of the adequacy parameter with the load utilisation factor.

Table 3.4.5 Adequacy parameter (AP)

LUF	AP
0,0	1,00
0,5	0,33
0,8	0,111
1,0	0,00
1,2	–0,091
1,5	–0,20
2,0	–0,33

Contents

Volume 2

■ *Section 1* Scope

1.1 Application

1.1.1 This Chapter covers the basis of the requirements for the design, construction, testing, installation, trials and through life changes of engineering systems installed in classed naval ships.

1.1.2 For the purposes of these Rules, an engineering system is considered to be a combination of interacting elements (sub-systems, equipment, components, hardware, software), organised to achieve one or more of the purposes stated in the Concept of Operations or the System Operational Concept documents.

1.1.3 These Rules are to be applied with reference to the operational conditions defined in the Concept of Operations, *see Vol 1, Pt 1, Ch 2, 2.2 Definitions*.

■ *Section 2* Engineering system classification provisions

2.1 Provisions

2.1.1 The classification provisions for engineering systems installed in naval ships address the following:

(a) The suitability and functioning of equipment and systems for maintaining the watertight and weathertight integrity of the hull, and spaces within the hull.
(b) The safety and reliability of engineering systems necessary for propulsion and steering and other engineering systems falling within the Mobility or Ship Type categories.
(c) The operation and functioning of systems installed for operational requirements relating to the ship type and additional Class notations excluding the operation and functioning of military systems.
(d) The effectiveness of systems which have been built into the ship in order to maintain basic conditions on board whereby appropriate stores, fuels, equipment and personnel can be safely carried whilst the ship is at sea, at anchor, or moored in harbour.

Section 3
Engineering system designation

3.1 Categories

3.1.1 For the purpose of classification, an Engineering System is defined as any system that may be installed in a ship where such a system comprises one or more sub-systems or components. For the purpose of determining the appropriate assessment process for engineering systems in naval ships, there are three categories:

(a) Mobility.
(b) Ship Type.
(c) Ancillary.

3.1.2 Mobility category engineering systems are those systems installed in order for the ship to proceed on operations and are necessary for:

(a) Maintaining the watertight and weathertight integrity of the hull and spaces within the hull.
(b) The safety and reliability of propulsion, steering and electrical systems.
(c) The operation and functioning of emergency machinery and equipment.

3.1.3 Ship Type category engineering systems are those systems installed in order for the ship to carry out its in-service purpose and are necessary for:

(a) The operation and functioning of the systems and equipment installed for purposes relating to the ship's in-service purpose excluding the operation and functioning of military systems.
(b) The operation and functioning of emergency machinery and equipment.

3.1.4 Ancillary category engineering systems are all systems other than Mobility category or Ship Type category, failure of which may compromise the provisions of Classification and are necessary for:

- The provision of basic conditions on board for the carriage of stores, fuels, equipment and personnel when the ship is at sea, at anchor, or moored in harbour.

3.1.5 Engineering Systems are to be assigned to the appropriate category taking into consideration the:

- ConOps for the vessel (*see Vol 1, Pt 1, Ch 2, 2.2 Definitions 2.2.16*);
- criteria in paragraphs *Vol 2, Pt 1, Ch 1, 3.1 Categories 3.1.1* to *Vol 2, Pt 1, Ch 1, 3.1 Categories 3.1.4* for Engineering Systems and the Mobility, Ship Type and Ancillary categories;
- dependency of Mobility or Ship Type engineering system upon other systems or services for their correct operation (e.g. if the propulsion plant's electronic control systems is cooled by chilled water, then the chilled water system is to be considered critical to the propulsion plant's function and assigned to the Mobility category);
- military systems and damage control arrangements relating to the Ship Type are to be stated where applicable.

3.1.6 Services such as the following are considered necessary for minimum comfortable conditions of habitability:

- cooking;
- heating and cooling;
- domestic refrigeration;
- mechanical ventilation;
- sanitary and fresh water.

3.1.7 Services such as the following, which are additional to those in *Vol 2, Pt 1, Ch 1, 3.1 Categories 3.1.5* and *Vol 2, Pt 1, Ch 1, 3.1 Categories 3.1.6*, are considered necessary to maintain the ship in a normal seagoing operational and habitable condition:

- hotel services, other than those required for habitable conditions;
- thrusters.

Section 4
Engineering system classification principles

4.1 Classification principles

4.1.1 Engineering system classification principles apply to all systems, equipment and components in order to achieve the provisions of classification. There are five groups of principles:

(a) Design principles.
(b) Construction principles.
(c) Installation, integration and test principles.
(d) Trials principles.
(e) Through life operation principles.

4.2 Design principles

4.2.1 Systems are to be designed, constructed and installed to minimise the risk of:

(a) harm to personnel
(b) damage to the platform
(c) damage to the environment

4.2.2 Systems and equipment are to be designed in accordance with the requirements of the relevant parts of the Rules.

4.2.3 Systems or components to be integrated into a higher level system are to be designed such that all their interfaces, electrical, mechanical, software or environmental, are clearly defined and compatible.

4.2.4 System integration is to be managed by a single designated party, and is to be carried out in accordance with a defined procedure identifying the roles, responsibilities and requirements for all parties involved. This procedure is to identify validation and verification activities to be undertaken and is to be submitted for consideration.

4.2.5 Systems are to be designed for the operating conditions defined in the Concept of Operations, *see Vol 1, Pt 1, Ch 2, 2.2 Definitions*, that are to include static and dynamic loads.

4.2.6 Mobility category and Ship Type category engineering systems are to be provided with means to monitor and identify potential failures that could lead to catastrophic, hazardous or major consequences and to notify users of degradation in systems performance that could lead to failures.

4.2.7 Mobility category and Ship Type category engineering systems are to be provided with means to detect failures that could lead to catastrophic, hazardous or major consequences and to notify users of such failures.

4.2.8 Systems are to remain in, or revert to, a safe state when failure occurs.

4.2.9 Systems and equipment are to be so designed such that they can be maintained and repaired effectively and safely.

4.2.10 Systems are to be so designed that a single failure will not result in the flooding of a watertight compartment from the sea.

4.2.11 Systems are to be arranged so that a single failure in equipment or loss of an associated sub-system will not result in failure, contamination or degradation of another system leading to a dangerous situation or loss of a Mobility or Ship Type category system.

4.2.12 Mobility and Ship Type category systems are to be such that key functions can be maintained in the event of a single failure in an operational sub-system.

4.2.13 Systems are to be provided with effective means of operation and control for all intended functions under all normal and abnormal operational modes.

4.3 Construction principles

4.3.1 The place of construction is to have suitable facilities for the construction, integration and testing of engineering equipment and systems.

4.3.2 Construction is to be in accordance with plans approved by Lloyd's Register (hereinafter referred to as 'LR') in accordance with the requirements of the relevant parts of the Rules.

4.3.3 Where required by the Rules, items are to be constructed under survey.

4.3.4 Materials are to be approved, manufactured and tested in accordance with a standard acceptable to LR.

4.3.5 Satisfactory operation and load testing is to be witnessed by LR where required by the Rules.

4.4 Installation, integration and test principles

4.4.1 Installation and integration are to be carried out in accordance with documentation approved by LR and relevant LR requirements.

4.4.2 Installation and integration are to be carried out under LR Survey.

4.4.3 Tests are to be conducted in accordance with LR requirements.

4.4.4 Integration tests are to verify that the integrated sub-systems and components operate correctly at the higher system level.

4.4.5 Any alterations to approved documentation are to be approved by LR.

4.4.6 Surveyable items not complying with approved documentation or LR requirements are to be replaced or rectified.

4.5 Trials principles

4.5.1 A trials schedule is to be agreed between the Builder, Naval Administration and LR and is to address LR Rule requirements.

4.5.2 The trials are to be conducted at agreed operating conditions and are to demonstrate the functional capability of engineering systems.

4.5.3 Emergency trips and emergency operating modes are to be demonstrated.

4.5.4 Where a Risk Assessment report, (*see Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*), has identified the need to prove the conclusions, testing and trials are to be carried out as necessary to investigate the following:

(a) The effect of a specific component failure.
(b) The effectiveness of automatic/manual isolation systems.
(c) The behaviour of any interlocks that may inhibit operation of Mobility or Ship Type systems.

4.5.5 The trials records are to be documented with sufficient detail to ascertain that the specified functional requirements of engineering systems have been satisfied. The records are to be available to enable any future trials to verify any significant degradation after in-service operation.

4.6 Through life operation principles

4.6.1 Engineering systems and equipment are to be operated and maintained such that the provisions of classification are achieved throughout the life of the vessel.

4.6.2 Modifications that may affect the provisions of classification are to be approved by LR.

4.6.3 Verification and validation activities are to be employed throughout the life of the ship to ensure compliance with the provisions of classification.

4.6.4 Suitable documentation is to be available to ensure that the provisions of classification can be performed effectively.

4.6.5 Persons with responsibilities for activities that may affect the provisions of classification are to be competent/ qualified to discharge those responsibilities.

4.6.6 The configuration of the vessel shall be identified and controlled throughout its life.

4.6.7 Operating and maintenance manuals for all engineering systems are to be provided on board and submitted to LR for information where requested and are to include the following information:

(a) Particulars of engineering systems.
(b) Operating instructions for all engineering systems, including recommended continuous operating design limits.
(c) Maintenance instructions for engineering systems and equipment.

(d) Instructions for normal and reversionary modes of operation for machinery and equipment in mobility and ship type engineering systems, *see Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.18*.

4.6.8 The operating and maintenance manuals required by *Vol 2, Pt 1, Ch 1, 4.6 Through life operation principles 4.6.7* are to be presented in a language and format that can be understood by the Operator.

■ *Section 5*
Acceptance criteria

5.1 Acceptance

5.1.1 The acceptance process ensures conformity of engineering systems to the provisions of Classification by assessing such systems against LR Rules and Regulations or their equivalent, and specified Standards or Codes.

5.1.2 The assessment process of engineering systems extends over the full lifecycle of the systems.

5.1.3 The assessment requirements applicable to engineering systems are dependent upon the system designation and are detailed in *Table 1.5.1 Assessment process for engineering systems*

Table 1.5.1 Assessment process for engineering systems

SYSTEM / PROCESS	MOBILITY CATEGORY	SHIP TYPE CATEGORY	ANCILLARY CATEGORY
DESIGN REVIEW	• Plans of all systems are to be appraised by LR • Procedure for component approval is to be agreed between the producer and LR • Procedure for component approval is to be agreed	• Plans to be appraised by LR when required by the Rules and where additional optional Class notation(s) are requested by Owners or Naval Administration	• Plans of system arrangements are to be reviewed by LR • Design review by LR where required by the Rules
CONSTRUCTION	• All major components and items of equipment are to be constructed under survey in accordance with plans approved by LR and Rule requirements	• To be constructed under survey when required by the Rules or Regulations	• No requirements unless required by the Rules
INSTALLATION	• To be installed under survey in accordance with plans approved by LR and Rule requirements	• To be installed under survey in accordance with plans approved by LR and Rule requirements	• No requirements unless required by the Rules
TRIALS	• To be tested under specified load conditions	• To be tested under normal working conditions	• Running test of systems under working conditions
IN SERVICE	• Subject to survey by the Rules or Regulations	• Subject to survey where required by the Rules or Regulations or requested by Owners or Naval Administration	• General examination

MODIFICATIONS	• Details of modifications are to be approved by LR • Construction, installation and trials are to be carried out under survey	• Details of any modifications are to be approved and construction, installation and trials are to be carried out under survey when not required by the Rules or Class notation	• Details of any modifications are to be recorded to enable review by LR Surveyors • Modifications are to be reviewed to ensure they do not change the category of the system
DE-COMMISSIONING	• Details are to be submitted for consideration	• Details are to be submitted for information	• Details are to be recorded

5.2 Military systems guidance

5.2.1 Where military systems are to be installed in accordance with a specified standard and the guidance within these Rules, the assessment process will be in accordance with the requirements for systems within the Ancillary category in *Table 1.5.1 Assessment process for engineering systems* and as detailed in *Vol 2, Pt 1, Ch 1, 5.2 Military systems guidance 5.2.2* to *Vol 2, Pt 1, Ch 1, 5.2 Military systems guidance 5.2.4*.

5.2.2 The proposed arrangements for compliance with Naval Administration requirements, the System Design Description, Rule guidance and any applicable Rule requirement where the system interfaces with the provisions of classification are to be assessed at a design review. This may be an LR specific design review or LR attendance at a design review organised by the Owner or Naval Administration.

5.2.3 Survey during installation will validate that the system has been installed with the particulars submitted.

5.2.4 Survey during service will be subject to agreement between LR and the Owner for individual installations.

■ *Section 6*
Routes to conformance

6.1 Design and construction

6.1.1 Plans/procedures as required by the Rules are to be approved by LR.

6.1.2 In general, LR acceptance of engineering systems or equipment is by the producer demonstrating compliance with the LR Type Approval system (*see Vol 2, Pt 1, Ch 1, 9 Type approval system (for information)*). Alternatively, approval of individual systems or equipment may be carried out on the basis of Design Appraisal combined with testing or acceptable service experience.

6.1.3 Conformance with the Construction Requirements of systems or equipment is to be demonstrated through compliance with Quality Assurance Scheme for Machinery or survey of individual items at the manufacturer's works.

6.1.4 Materials are to have certificates acceptable to LR, *see Vol 2, Pt 1, Ch 1, 7 Certification of materials*.

6.1.5 Testing of components, equipment and systems after manufacture is to comply with the Rules and any applicable standards and codes.

6.2 Machinery to be constructed under survey

6.2.1 All major units of equipment within the Mobility category, and where specifically required within the Ship Type category and Ancillary category, are to be individually surveyed at the manufacturer's works or meet the requirements of the Quality Assurance Scheme for Machinery. The workmanship is to be to the Surveyor's satisfaction and the Surveyor is to be satisfied that the components are suitable for the intended purpose and duty. Examples of such units are:

- Main propulsion prime movers (oil engines, gas turbines and steam turbines) including their associated gearing, flexible couplings and turbochargers as applicable.
- Boilers supplying steam for propulsion or for services essential for the safety or the operation of the ship at sea, including superheaters, economisers, desuperheaters, steam heated steam generators and steam receivers. All other boilers having working pressures exceeding 3,4 bar and having heating surfaces greater than 4,65 m^2.
- Auxiliary engines which are the source of power for services essential for safety or for the operation of the ship at sea.
- Steering machinery.
- Athwartship thrust units, their prime movers and control mechanisms.
- All pumps necessary for the operation of main propulsion and essential machinery, e.g. boiler feed, cooling water circulating, condensate extraction, fuel oil and lubricating oil pumps.
- All heat exchangers necessary for the operation of main propulsion and essential machinery, e.g. air, water and lubricating oil coolers, fuel oil and feed water heaters, de-aerators and condensers, evaporators and distiller units.
- Air compressors, air receivers and other pressure vessels necessary for the operation of main propulsion and essential machinery. Any other unfired pressure vessels for which plans are required to be submitted as detailed in *Vol 2, Pt 8, Ch 2 Other Pressure Vessels*
- All pumps essential for safety of the ship, e.g. fire, bilge and ballast pumps.
- Valves and other components intended for installation in essential piping systems, *see Vol 2, Pt 7, Ch 1, 2.2 Definitions 2.2.1* having working pressures exceeding 7 bar.
- Alarm and control equipment as detailed in *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*
- Electrical equipment and electrical propelling machinery as detailed in *Vol 2, Pt 9 Electrotechnical Systems*

6.3 Survey for classification

6.3.1 The Surveyors are to examine and test the materials and workmanship from the commencement of work until the final test of the machinery under full power and any other specified working conditions. Any defects, etc. are to be indicated as early as possible. On completion, a certificate will be issued and an appropriate notation will be assigned in accordance with the Regulations.

6.4 Alternative system of inspection

6.4.1 Where items of machinery are manufactured as individual or series produced units, consideration will be given to the adoption of a survey procedure based on quality assurance concepts utilising regular and systematic audits of the approved manufacturing and quality control processes and procedures as an alternative to the direct survey of individual items.

6.4.2 In order to obtain approval, the requirements of *Vol 2, Pt 1, Ch 1, 8 Quality assurance scheme for machinery* are to be complied with.

6.5 Installation

6.5.1 Where required by the assessment process in *Table 1.5.1 Assessment process for engineering systems*, engineering systems are to be installed under survey in accordance with approved plans and relevant LR Design Appraisal documentation and LR Rules.

6.5.2 Documentation required during installation is to be available for inspection by the Owners and LR Surveyors. Such documentation may include:

- Design Appraisal Documents.
- Type Test Certificates.
- Materials Certificates.
- Type Approval Certificates.
- Quality Assurance Certificates.
- Certificates of Construction.

6.6 Trials

6.6.1 Engineering systems are to be tested on completion of installation to demonstrate functionality and suitability for purpose in accordance with LR Rules.

6.6.2 Records of trials and testing required by the assessment process in *Table 1.5.1 Assessment process for engineering systems* are to be maintained on board the ship.

6.7 In-service survey

6.7.1 Where required by the assessment process in *Table 1.5.1 Assessment process for engineering systems* and in the Regulations, engineering systems are to be surveyed at intervals defined in the Regulations.

6.7.2 Records of in-service survey where carried out by the Marine Engineering Officer are to be maintained on board the ship, as defined in the Regulations.

6.8 Modifications

6.8.1 Details of modifications to engineering systems or equipment are, as required by *Table 1.5.1 Assessment process for engineering systems* to be submitted to LR for consideration.

6.8.2 Records of all modifications to in-service engineering systems that may alter the provisions of classification, are to be maintained on board the ship.

6.9 De-commissioning

6.9.1 Details of de-commissioning of engineering systems, as required by *Table 1.5.1 Assessment process for engineering systems*, are to be submitted to LR for consideration.

6.9.2 Records of de-commissioning of all equipment and systems that may alter the provisions of classification are to be maintained on board the ship.

6.10 Upkeep by exchange

6.10.1 Where propulsion and auxiliary machinery is maintained using an ‘upkeep by exchange’ policy, details of the system are to be submitted to LR for approval.

6.10.2 Where an ‘upkeep by exchange’ system has been approved, plans of individual replacement units are not required to be submitted provided there have been no changes since the original approval. The manufacture and testing of the replacement units is to be in accordance with the relevant Rule requirements.

6.10.3 Records of each ‘upkeep by exchange’ are to be maintained on board the ship and LR is to witness running tests on load after each exchange. A record history is to be maintained for each exchange unit in the form of a log book.

6.11 Alternative arrangements and calculation methods

6.11.1 In addition to cases where direct calculations are specifically required by the Rules, LR will consider alternative arrangements that have been derived by direct calculations in lieu of specific Rule requirements. All direct calculations are to be submitted for examination.

6.11.2 Where items are of a novel or unconventional design or manufacture, it is the responsibility of the designer to demonstrate their suitability and equivalence to the Rule requirements. *See Requirements for Machinery and Engineering Systems of Unconventional Design*, *Vol 2, Pt 1, Ch 2 Requirements for Machinery and Engineering Systems of Unconventional Design*.

6.11.3 Alternative arrangements or fittings that are considered to be equivalent to the Rule requirements will be accepted in accordance with *Vol 1, Pt 1, Ch 3, 3.2 Hull*.

■ *Section 7*
Certification of materials

7.1 Materials of construction

7.1.1 Materials used in the construction are to be in accordance with, or shown to be equivalent to *Rules for the Manufacture, Testing and Certification of Materials, July 2015* (hereinafter referred to as the Rules for Materials). Details of all materials included and not included in are to be forwarded as soon as possible (preferably at the design concept stage) and before commencement of manufacture.

7.2 Welding

7.2.1 Welding consumables, plant and equipment are to be in accordance with the requirements specified in *Ch 13, 1.8 Welding equipment and welding consumables* of the Rules for Materials.

7.2.2 Welding procedures and welder qualifications are to be tested and qualified in accordance with the requirements specified in *Ch 12 Welding Qualifications* of the Rules for Materials.

7.2.3 Production weld tests are to be carried out where specified in the subsequent Chapters of these Rules.

7.2.4 All finished welds are to be subjected to non-destructive examination in accordance with the requirements specified in *Ch 13, 2.12 Non-destructive examination of welds* of the Rules for Materials and or the requirements specified in the subsequent chapters of these Rules.

■ *Section 8*
Quality assurance scheme for machinery

8.1 General

8.1.1 The Quality Assurance Scheme for Machinery (QAM Scheme) is an alternative to direct survey and certification of machinery components and equipment required by the Rules. Under the QAM Scheme LR will consider the extent to which manufacturing processes and control procedures ensure conformity of that machinery to Rules, technical specifications and any other applicable standards or codes.

8.1.2 This QAM Scheme is applicable to items manufactured under closely controlled conditions. A list of products for which the QAM Scheme is applicable is provided in LR's *ShipRight Procedure Approval of a Manufacturer according to the Quality Assurance Scheme for Machinery*.

8.1.3 The QAM Scheme does not reduce the test requirements to be carried out in accordance with LR's Rules.

8.2 Definitions

8.2.1 The following definitions apply in the context of this Section:

8.2.2 QAM Scheme audit

An audit, conducted by LR at the manufacturer's, or their supplier's or sub-contractor's works, of their products and/or processes, which may include direct survey, in order to provide confidence that products are manufactured, tested and inspected in accordance with LR's Rules. Periodicity of surveillance audits is as agreed in the QAM Scheme Certification Schedule, *see* LR's *ShipRight Procedure Approval of a Manufacturer according to the Quality Assurance Scheme for Machinery*.

8.2.3 Assessment

A review, conducted by LR, of evidence gained through a number of sources, such as documentation, submitted by the manufacturer or supplier or sub-contractor, and regular QAM Scheme audit reports, in order to verify that products are manufactured, tested and inspected in accordance with the Rules.

8.2.4 Manufacturer

A company that contracts to supply components or equipment products to a customer or user and applies for approval under the QAM Scheme.

8.2.5 Supplier

A company that contracts to supply materials, components or equipment products to the Manufacturer applying for approval under the QAM Scheme.

8.3 QAM Scheme Arrangements

8.3.1 A manufacturer may apply to be approved under the QAM Scheme where the following requirements are met:

(a) The manufacturer has a quality management system which has been certified as meeting the requirements of ISO 9001, or industry-specific equivalent standard, by a certification body accredited by a member of the International Accreditation Forum and recognised by LR.
(b) The manufacturer has processes in place suitable for the products to be certified under the QAM Scheme.
(c) The manufacturer has a satisfactory and documented history of quality performance in the supply of products for which certification under the QAM Scheme is requested.

8.3.2 The scope and arrangements for survey, identification and certification of products covered by the QAM Scheme are to be agreed with LR and will be detailed in a Scheme Certification Schedule. The Survey will be based on a technical audit approach, focussing on product realisation. Direct survey may also be used where it is considered appropriate to do so.

8.3.3 The QAM Scheme procedures given in LR's *ShipRight Procedure Approval of a Manufacturer according to the Quality Assurance Scheme for Machinery* are to be complied with.

8.3.4 Where LR is satisfied that the manufacturer meets all of the requirements of the QAM Scheme, and that it is appropriate for the products being manufactured, LR will issue the manufacturer with a QAM Scheme Certificate which will list products covered.

8.3.5 LR reserves the right to carry out unscheduled audits, with appropriate notice, at the manufacturer's works or their suppliers' and sub-contractors' works.

8.3.6 Once every three years, a full re-certification assessment of QAM Scheme compliance, including an audit of the manufacturer's works, will be conducted by LR.

8.3.7 The manufacturer is to advise LR of changes to the product, processes or suppliers or sub-contractors which would affect compliance with the QAM Scheme or LR's Rules. Any deviations from the approved plans or specifications are to be reported to LR and written approval obtained prior to dispatch of the items.

8.3.8 Where it is considered that the manufacturer no longer meets the approval requirements for the QAM Scheme, the QAM Scheme Certificate will be suspended. In these circumstances, the manufacturer will be notified in writing of LR's reasons for suspension of the scheme and the manufacturer will revert to direct survey and issue of LR certificates.

8.3.9 **QAM Scheme product certificates**. Where the manufacturer is approved according to the QAM Scheme, they will be entitled to issue 'QAM Scheme product certificates'. These certificates are to clearly detail the product being certified and are to be validated by an authorised representative of the manufacturer. The certificates are to be countersigned by LR to certify that the Rule requirements for that product are being met.

8.4 Acceptance of purchased materials, components and equipment

8.4.1 The manufacturer is to establish and maintain procedures and controls to ensure compliance with LR's requirements for certification of products from its suppliers. The manufacturer is to ensure that purchased products that are required to be certified in accordance with *Ch 3 Rolled Steel Plates, Strip, Sections and Bars* to *Ch 10 Equipment for Mooring and Anchoring* of the Rules for Materials are made at works which have been approved by LR for the type and grade of product being supplied. The manufacturer's system for control of purchased products is to be based on one or a combination of the following alternatives:

(a) Product certification by LR at the supplier's works in accordance with the requirements of the Rules.
(b) Product certification by a supplier separately approved by LR under the QAM Scheme or other LR Quality Scheme covering those products.
(c) Product certification by the manufacturer in accordance with quality processes for control of suppliers of purchased products included within the scope of the manufacturer's QAM Scheme approval. These quality schemes are to ensure compliance with Rule requirements for the purchased products.

8.4.2 **Manufacturers' certificates issued under the QAM Scheme**.

Where the manufacturer's system for control of purchased products from suppliers is based on *Vol 2, Pt 1, Ch 1, 8.4 Acceptance of purchased materials, components and equipment 8.4.1* and Surveyors have confirmed that LR Rules are being satisfied, the manufacturer will be permitted to accept 'Manufacturers' certificates issued under the QAM Scheme', in lieu of LR Certificates for purchased products. The certificates must bear the QAM Scheme mark and the following statement:

'This certificate is issued under the arrangements authorised by Lloyd's Register (operating entity, e.g. EMEA) in accordance with the requirements of the Quality Assurance Scheme for Machinery and Scheme number, QAM……..'

Section 9
Type approval system (for information)

9.1 General

9.1.1 LR Type Approval is an impartial certification system that provides independent third-party Type Approval Certificates attesting to a product's conformity with specific standards or specifications. It is based on design review and type testing or where testing is not appropriate, a design analysis.

9.1.2 The LR Type Approval System is a process whereby a product is assessed in accordance with a specification, standard or code to check that it meets the stated requirements and through selective testing prove its suitability for its intended operation. The testing is carried out on a prototype or randomly selected product(s) which are representative of the manufactured product under approval. Thereafter, the manufacturer testifies that each item delivered is in conformity with that which has been type tested.

9.1.3 Details of LR's Type Approval System are contained in the following LR publications:

(a) Procedure TA02.
(b) Test Specification 1: Electrical and Control Engineering Products which are Environmentally Tested.
(c) Test Specification 2: Piping System Components.
(d) Test Specification 3: Electrical products that do not require Environmental Testing.
(e) Test Specification 4: *Type Testing of Reciprocating Internal Combustion Engines and Associated Ancillary Equipment.*
(f) Test Specification GT04: Gas Turbines.

9.2 Approval criteria

9.2.1 LR Type Approval does not preclude inspection and survey procedures required by these Rules for equipment to be installed in naval ships classed or intended to be classed with LR.

9.2.2 LR Type Approval is subject to the understanding that the producer's recommendations and instructions for the product and any relevant requirements of these Rules are fulfilled.

9.2.3 Where equipment or components have been type approved in accordance with procedures other than LR's, details of the product, certification and testing are to be submitted for consideration.

■ Section 1 Requirements for machinery and engineering systems of unconventional design

1.1 General – Scope and objectives

1.1.1 The requirements of this Section aim to ensure that risks to maritime safety and the environment, stemming from the introduction of machinery or engineering systems of unconventional design, are addressed insofar as they affect the objectives of naval classification.

1.1.2 The requirements of this Section are to be satisfied where machinery is required to be constructed, installed and tested in accordance with Lloyd's Register's (LR's) Rules and Regulations and for which the corresponding machinery class notation is to be assigned, *see Vol 1, Pt 1, Ch 2, 3.9 Machinery and Engineering Systems notations*.

1.1.3 The requirements apply to machinery and engineering systems considered by LR to be of unconventional design and which, as a result, are not directly addressed by LR's extant Rules and Regulations. It should be noted however, that the general requirements of LR's Rules and Regulations are to be satisfied as applicable.

1.1.4 Compliance with ISO/IEC15288 *Systems Engineering – System Life Cycle Processes* or an acceptable equivalent National Standard may be accepted as meeting the requirements of *Vol 2, Pt 1, Ch 2, 1.3 Project management*.

1.2 Documents required for design review

1.2.1 Information is to be submitted for assessment of compliance with the general requirements of LR's Rules and Regulations, including the general requirements for:

(a) Machinery, *see Vol 2, Pt 1, Ch 1 General Requirements for Classification of Engineering Systems* and *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*;
(b) Steam raising plant and pressure vessels *see Vol 2, Pt 8, Ch 1 Steam Raising Plant and Associated Pressure Vessels* and *Vol 2, Pt 8, Ch 2 Other Pressure Vessels*;
(c) Machinery and ship piping systems, *see Vol 2, Pt 7, Ch 2 Ship Piping System*, *Vol 2, Pt 7, Ch 3 Machinery Piping Systems* and *Vol 2, Pt 7, Ch 5 Ship Type Piping Systems*;
(d) Control, Alerts and Safety Systems, *see Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*;
(e) Electrotechnical Systems, *see Vol 2, Pt 9 Electrotechnical Systems*;
(f) Materials, *see* the *Rules for the Manufacture, Testing and Certification of Materials, July 2015* .

1.2.2 In addition to the information identified in *Vol 2, Pt 1, Ch 2, 1.2 Documents required for design review 1.2.1*, the information described in *Vol 2, Pt 1, Ch 2, 1.2 Documents required for design review 1.2.3* and *Vol 2, Pt 1, Ch 2, 1.2 Documents required for design review 1.2.4* is also to be submitted for consideration.

1.2.3 A System Design Description detailing the extent of the machinery or engineering system is to be provided. This is to describe the shipboard services the system is to provide, its operating principles, and its functionality and capability when operating in the environment to which it is likely to be exposed under both normal and foreseeable abnormal conditions. *See Vol 2, Pt 1, Ch 3, 3.5 System design description* The System Design Description is to be supported by the following information as applicable:

(a) System block diagram.
(b) Piping and instrumentation diagrams.
(c) Description of operating modes, including: Start-up, shutdown, automatic, reversionary, manual and emergency.
(d) Description of safety related arrangements, including: Safeguards, automatic safety systems and interfaces with ships' safety systems.
(e) Description of connections to other shipboard machinery, equipment and systems, including:

Electrical, mechanical, fluids and automation.

(f) Plans of physical arrangements, including: Location, operational access and maintenance access.
(g) System Operational Concept document, where appropriate, *see Vol 2, Pt 1, Ch 3, 3.4 System operational concept*.
(h) Operating manuals, including:

Instructions for start-up, operation, shutdown, instructions for maintenance, instructions for adjustments to the performance and functionality and details of risk mitigation arrangements.
(i) Maintenance manuals, including:

Instructions for routine maintenance, repair following failure, disposal of components and recommended spares inventory.

1.2.4 Project process documentation including:

(a) Project Management Plan, *see Vol 2, Pt 1, Ch 2, 1.3 Project management*;
(b) Requirements Definition Document, *see Vol 2, Pt 1, Ch 2, 1.4 Requirements definition*;
(c) Quality Assurance Plan, *see Vol 2, Pt 1, Ch 2, 1.5 Quality assurance*;
(d) Design Definition Document, *see Vol 2, Pt 1, Ch 2, 1.6 Design definition*;
(e) Risk Management Plan, *see Vol 2, Pt 1, Ch 2, 1.7 Risk management*;
(f) Configuration Management Plan, *see Vol 2, Pt 1, Ch 2, 1.8 Configuration management*;
(g) Verification Plan, *see Vol 2, Pt 1, Ch 2, 1.9 Verification*;
(h) Integration Plan, *see Vol 2, Pt 1, Ch 2, 1.10 Integration*;
(i) Validation Plan (certification and survey), *see Vol 2, Pt 1, Ch 2, 1.11 Validation (certification and survey)*.

1.3 Project management

1.3.1 A project management procedure is to be established in order to define and manage the key project processes. The project processes are to include the processes described in *Vol 2, Pt 1, Ch 2, 1.4 Requirements definition* to *Vol 2, Pt 1, Ch 2, 1.11 Validation (certification and survey)*.

1.3.2 For the entire project, and each of the processes within the project, the project management procedure is to define the following:

(a) Activities to be carried out.
(b) Required inputs and outputs.
(c) Roles of key personnel.
(d) Responsibilities of key personnel.
(e) Competence of key personnel.
(f) Schedules for the activities.

1.4 Requirements definition

1.4.1 A requirements definition procedure is to be established in order to define the functional behaviour and performance of the machinery or engineering system required by individual stakeholders, in the environments to which the machinery or engineering system is likely to be exposed under both normal and foreseeable emergency conditions.

1.4.2 The procedure is to take account of requirements resulting from key stakeholders, including:

(a) Ship's owner.
(b) Ship's operator.
(c) Ship's crew.
(d) Shipyard.
(e) Systems integrator.
(f) Designers.
(g) Maintenance personnel.
(h) Surveyors.
(i) Manufacturers and suppliers.
(j) Naval Administration.
(k) LR.

1.4.3 The procedure is to take account of requirements resulting from the following influences:

(a) Operations that the ship is intended to perform during trials, at sea, while docking and training exercises, including those related to mission specific activities and degraded and reversionary modes of operation.
(b) Ship conditions during normal operations and conditions arising from accidents or reasonable foreseeable failures or misuse of ship equipment or systems.
(c) The environmental conditions that the equipment or systems will experience due to their location within the ship and due to the geographical location of the ship.
(d) The requirements of applicable legislation, naval, National and International Standards and classification rules, codes of practice and other instruments agreed by the key stakeholders.
(e) The number, availability, competence and overall capability of personnel involved with the use, maintenance, assessment and supervision of the system during ship operations.
(f) Design constraints identified through consideration of the lifecycle of the ship.

1.4.4 The procedure is to specify the functional behaviour and performance requirements and is to identify the source of the requirements.

1.5 Quality assurance

1.5.1 A quality assurance procedure is to be established in order to ensure that the quality of the machinery or engineering system is in accordance with a defined quality management system.

1.5.2 The procedure is to define the specific quality controls to be applied during the project in order to satisfy the requirements of the quality management system.

1.5.3 The quality management system is to satisfy the requirements of ISO9001:2000 *Quality management systems – Requirements*, or an equivalent acceptable National Standard.

1.6 Design definition

1.6.1 A design definition procedure is to be established in order to define the requirements for the design of machinery or an engineering system which satisfies stakeholder requirements, quality assurance requirements and complies with basic internationally recognised design requirements for safety and functionality.

1.6.2 The procedure is to ensure that the design of the machinery or engineering system satisfies:

(a) Statutory legislation.
(b) LR's requirements.
(c) International Standards and codes of practice where relevant.

1.6.3 The procedure is to take account of stakeholder requirements, *see Vol 2, Pt 1, Ch 2, 1.4 Requirements definition*.

1.6.4 The procedure is to take account of quality assurance requirements, *see Vol 2, Pt 1, Ch 2, 1.7 Risk management*.

1.6.5 The procedure is to ensure that the requirements for the design of major components and subsystems of the machinery or engineering system can be verified before and after integration.

1.6.6 The procedure is to specify the design requirements and is to identify the source of the requirements.

1.6.7 Any deviations from stakeholder requirements are to be identified, justified and accepted by the originating stakeholder.

1.7 Risk management

1.7.1 A risk management procedure is to be established in order to ensure that any risks stemming from the introduction of the machinery or engineering system are addressed, in particular risks affecting:

(a) The structural strength and integrity of the ship's hull.
(b) The safety of shipboard machinery and engineering systems.
(c) The safety of shipboard personnel.
(d) The reliability of Mobility systems, Ship Type systems, emergency machinery and engineering systems.
(e) The environment.

1.7.2 The procedure is to consider the hazards associated with installation, operation, maintenance and disposal both with the machinery or engineering system functioning correctly and following any reasonably foreseeable failure.

1.7.3 The procedure is to take account of stakeholder requirements, *see Vol 2, Pt 1, Ch 2, 1.4 Requirements definition*.

1.7.4 The procedure is to take account of design requirements, *see Vol 2, Pt 1, Ch 2, 1.6 Design definition*.

1.7.5 The procedure is to ensure that hazards are identified using acceptable and recognised hazard identification techniques, (*see Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*), and that the effects of the following influences are considered:

(a) Operations that the ship is intended to perform during trials, in service, while docking and in harbour, including those related to mission specific activities and degraded and reversionary modes of operation.
(b) Ship conditions under normal and reasonably foreseeable abnormal operating conditions arising from failures or misuse of ship equipment or systems.
(c) Configurations and modes of operation provided for the intended control of machinery and engineering systems.
(d) The environmental conditions that the equipment or systems will experience due to their location within the ship and due to the geographical location in which the ship operates.
(e) The reliance and effects on the operation of engineering systems and machinery of the provision and availability of supplies and services and user interaction, including assessment of interdependencies.
(f) The environmental impact of the ship throughout its lifecycle.

1.7.6 The procedure is to ensure that risks are analysed using acceptable and recognised Risk Assessment techniques, (*see Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*), and that the following consequences are considered:

(a) Loss of function.
(b) Loss of services essential to the safety of the ship, services essential to the safety of shipboard personnel and services essential to the protection of the environment.
(c) Damage to components.
(d) Damage caused by fire, explosion, electric shock, harmful releases and hazardous releases.

1.7.7 The procedure is to ensure that risks are eliminated wherever possible. Risks which cannot be eliminated are to be mitigated as necessary.

1.7.8 Details of risks, and the means by which they are mitigated, are to be included in the operating manual, *see Vol 2, Pt 1, Ch 2, 1.2 Documents required for design review 1.2.3*.

1.8 Configuration management

1.8.1 A configuration management procedure is to be established in order to ensure traceability of the configuration of the machinery or engineering system, its subsystems and its components.

1.8.2 The procedure is to identify items essential for the safety or operation of the machinery or engineering system, and which could foreseeably be changed during the life time of the machinery or engineering system, including:

(a) Documentation.
(b) Software.
(c) Sensors.
(d) Actuators.
(e) Instrumentation modules, boards and cards.
(f) Valves.
(g) Pumps.

1.8.3 The procedure is to take account of the design requirements, *see Vol 2, Pt 1, Ch 2, 1.6 Design definition*.

1.8.4 The procedure is to include items used to mitigate risks, *see Vol 2, Pt 1, Ch 2, 1.7 Risk management*.

1.8.5 The procedure is to ensure that any changes to configuration control items are:

(a) Identified.
(b) Recorded.
(c) Evaluated.
(d) Approved.
(e) Incorporated.
(f) Verified.

1.9 Verification

1.9.1 A verification procedure is to be established in order to ensure that subsystems and major components of the machinery or engineering system satisfy their design requirements.

1.9.2 The procedure is to verify design requirements, *see Vol 2, Pt 1, Ch 2, 1.6 Design definition*.

1.9.3 The procedure is to identify the requirements to be verified, the means by which they are to be verified, and the points in the project at which verification is to be carried out.

1.9.4 The procedure is to be based on one or a combination of the following activities as appropriate:

(a) Design review.
(b) Product inspection.
(c) Process audit.
(d) Product testing.

1.10 Integration

1.10.1 An integration procedure is to be established in order to ensure that the machinery or engineering system is assembled in a sequence which allows verification of individual subsystems and major components following integration in advance of validating the entire machinery or engineering system.

1.10.2 The procedure is to take account of the verification requirements, *see Vol 2, Pt 1, Ch 2, 1.9 Verification*.

1.10.3 The procedure is to identify the subsystems and major components, the sequence in which they are to be integrated, the points in the project at which integration is to be carried out, and the points in the project at which verification is to be carried out.

1.11 Validation (certification and survey)

1.11.1 A validation procedure is to be established in order to ensure the functional behaviour and performance of the machinery or engineering system meets with its functional and performance requirements.

1.11.2 The procedure is to validate stakeholder requirements, *see Vol 2, Pt 1, Ch 2, 1.4 Requirements definition*.

1.11.3 The procedure is to validate arrangements required to mitigate risks, *see Vol 2, Pt 1, Ch 2, 1.7 Risk management*.

1.11.4 The procedure is to validate the traceability of the configuration control items, *see Vol 2, Pt 1, Ch 2, 1.8 Configuration management*.

1.11.5 The procedure is to identify the requirements to be validated, the means by which they are be validated and the points in the project at which validation is to be carried out, including:

(a) Factory acceptance testing.
(b) Integration testing.
(c) Commissioning.
(d) Sea trials.
(e) Survey.

Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems

■ *Section 1* Scope

1.1 Application

1.1.1 This Chapter applies to the design, construction, installation and testing of Mobility, Ship Type, and Ancillary category engineering systems for classed naval ships and covers:

- Main propulsion systems.
- Steering and manoeuvring systems.
- Electrical power systems.
- Auxiliary machinery systems.
- Other engineering systems necessary for the watertight and weathertight integrity and functioning of ship type features.
- Together with their equipment, pressure plant, piping systems, control engineering and electrical engineering systems.

1.1.2 Additional requirements for individual systems and components are detailed in the following Parts.

Section 2
General provisions

2.1 Provisions

2.1.1 The units and formulae used in the Rules are in SI Units.

2.1.2 It is the responsibility of the Shipbuilder as main contractor to ensure that the documentation required is prepared and submitted in accordance with a project schedule which has been agreed by LR.

2.1.3 The main propulsion machinery will be approved for the maximum continuous power, and associated shaft speed or equivalent design and performance criteria.

2.1.4 Main propulsion machinery will be considered for operation at a higher power rating than the classification rating for short time intervals (referred to as short-term high power operation) in conjunction with the intended operation service profile.

2.1.5 Facilities are to be provided for cleaning, inspection and maintenance of main propulsion and auxiliary machinery including boilers and pressure vessels.

2.1.6 Where it is proposed to depart from the requirements of the Rules, an Engineering and Safety Justification, *see Vol 1, Pt 1, Ch 2, 2.2 Definitions* is to be submitted to Lloyd's Register ('LR') for consideration.

2.1.7 Any novelty in the design and/or construction of machinery, boilers, pressure vessels or engineering equipment is to be advised to LR (*see also Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*).

Section 3
Documentation required for design review

3.1 Submission of information

3.1.1 The documentation described in *Vol 2, Pt 1, Ch 3, 3.2 Documentation* is to be submitted for design review before manufacturing has started.

3.2 Documentation

3.2.1 Plans are to indicate clearly the scantlings and materials of construction. Any design alteration to the plan is to be resubmitted for approval, indicating clearly the alteration.

3.2.2 The following arrangement plans and documentation are required,

(a) Plans showing the arrangement of machinery spaces indicating the location of machinery and equipment together with means of access and ventilation;
(b) Plans showing the maintenance envelope and removal routes of machinery and equipment where routine removal for maintenance is proposed;
(c) System Operational Concept documents, where required by *Vol 2, Pt 1, Ch 3, 3.4 System operational concept*;
(d) System Design Descriptions, *see Vol 2, Pt 1, Ch 3, 3.5 System design description*; and
(e) Documentation as required by the individual Chapters for specific machinery and electrotechnical systems or components. This is to include their System Design Descriptions, *see Vol 2, Pt 1, Ch 3, 3.5 System design description*.

Where elements or sub-systems are to be integrated into a higher level system, an interface definition document shall be submitted detailing all the interfaces between them, electrical, mechanical, software or environmental. The level of detail provided shall enable the system integrator to assess their compatibility for correct operation as part of the higher level system.

3.2.3 Where machinery system components have been approved under LR’s Type Approval System or Quality Assurance Scheme for Machinery for the proposed design conditions or service, plans of the component are not required to be submitted. Full details of the components and the existing LR approval are to be submitted.

3.2.4 Where operating requirements relating to the design, construction, testing, installation, and integration of machinery and engineering systems have been defined within the scope of *Vol 2, Pt 1, Ch 3, 4 Operating conditions*, evidence of capability and details of previous or proposed testing to demonstrate capability are to be submitted.

3.2.5 Where an oil or liquefied petroleum gas fired galley is proposed, details of the oil and gas storage and distribution arrangements together with ventilation arrangements and safety shutdown and alarms are to be submitted.

3.3 Calculations and specifications

3.3.1 **Service Profile.** The machinery power/speed operational envelope, grade(s) of fuel and any short-term high power operation.

3.3.2 **Classification rating.** The following operational parameters, using the design conditions for the intended Class Notation(s):

Total barometric pressure, bar.

Temperature of engine room, or suction air, ºC.

Relative humidity, per cent.

Maximum/minimum temperatures of sea water, or
charge air coolant inlet, ºC.

See Vol 2, Pt 1, Ch 3, 4.4 Ambient reference conditions 4.4.1 for ambient reference conditions.

3.3.3 **Short-term high power operation.** Where the propulsion machinery is being considered for short-term high power operation, full details of the power, speed and time intervals together with fatigue endurance calculations, and documentary evidence indicating the suitability of the component design under these conditions and for the intended class notation are required. The following are to be considered; prime mover, gearbox, flexible coupling, vibration dampers, shafting and propeller:

(a) The accrued number of load cycles and the percentage component overload are to be those recommended by the designers.
(b) Excessive overload may require the interval between surveys to be reduced.
(c) Plans showing the arrangement of resiliently mounted machinery which are to indicate the number, position, type and design of the mounts.
(d) Machinery is to be maintained in accordance with manufacturer's requirements.
(e) For electric propulsion:
    (i) The prime mover rated power in conjunction with its overloading and load build-up capabilities shall be adequate to supply the power needed during transitional changes in operating conditions of the electrical equipment due to manoeuvring and sea and weather conditions.
    (ii) Reverse power:

    When manoeuvring, for example from full propeller speed ahead to maximum design propeller speed astern with the ship making full way ahead, the prime-mover shall be capable of absorbing a proportion of the regenerated power without tripping due to overspeed or reverse power.

Means external to the mechanical and electrical rotating machinery may be provided in the form of, for example, braking resistors to absorb excess amounts of regenerated energy and to reduce the speed of the propulsion motor. The amount of regenerated power shall be limited by the control system. Generators operating with semiconductor converters shall be designed for the expected harmonics of the system. A sufficient reserve shall be considered for the temperature rise, compared with sinusoidal load.

3.3.4 **Damper and Flexible Coupling characteristics.** Documentary evidence that the characteristics have been verified.

3.3.5 **Machinery Fastening.**

(a) For NS3 type ships or where specified for other ship types, documentary evidence and calculations indicating that machinery is securely mounted for the ship motions and accelerations to be expected during service.
(b) For NS3 type ships or where specified for other ship types, calculations to demonstrate that mountings of large masses such as main engines, auxiliary engines and electrical equipment can withstand the design collision acceleration according to *Vol 2, Pt 1, Ch 3, 5.4 Collision load 5.4.1* without fracturing.

(c) Plans showing the arrangement of resiliently mounted machinery which are to indicate the number, position, type and design of mounts.
(d) Natural frequency calculation of resilient mounted machinery.
(e) Plans showing the arrangement of resin chocks for machinery requiring accurate alignment with the following information:
    (i) Resin type.
    (ii) The effective area and minimum thickness of the chocks.
    (iii) The total deadweight loading of machinery.
    (iv) The thrust load, where applicable, that will be applied to the chocked item.
    (v) The loading to be applied to the holding-down bolts.
    (vi) The material of the holding-down bolts.
    (vii) The number, thread size, and waisted shank diameter (where applicable) of the holding-down bolts.

See Vol 2, Pt 1, Ch 3, 5.3 Machinery fastenings for requirements.

3.3.6 **Manuals.** The operation and maintenance manuals. For class notations covering propulsion and steering machinery redundancy, *see Vol 3 Additional Optional Requirements*

3.3.7 A Risk Assessment (RA), in accordance with the guidance in *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*, is to be carried out, covering the following systems:

(a) Main and auxiliary machinery systems supporting propulsion, steering, Mobility systems or Ship Type systems.
(b) Steering systems.
(c) Electrical generation and distribution systems supporting *Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.7* and *Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.7*, *see Vol 2, Pt 10, Ch 1, 6.2 Physical environment 6.2.4*.

This requirement is in addition to the requirements for class notations covering propulsion and steering machinery redundancy, and Ship Type piping systems (*see Vol 2, Pt 7, Ch 5 Ship Type Piping Systems*).

3.3.8 **Fatigue Strength Analysis.** Where undertaken as an alternative to the requirements of the individual Chapters, fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads based on a suitable fatigue failure criteria. The effects of stress concentrations, material properties and operating environment are to be taken into account.

3.3.9 **CBRN Protection arrangements**. Where the CBRN Protection requirements are specified, a design statement together with plans and particulars are to be submitted for information. *See Vol 2, Pt 1, Ch 3, 4.12 Guidance for CBRN protection, detection and monitoring* for CBRN Protection guidance.

3.3.10 **Machinery shock resistance arrangements**. Where shock capability requirements for machinery, engineering systems and equipment have been specified, the requirements of *Vol 2, Pt 1, Ch 3, 4.11 Machinery shock arrangements* apply and the following details are to be submitted:

(a) The shock policy for the ship. This shall include the shock environment to be used for shock calculations; this will remain confidential to LR.
(b) A design statement that details the shock capability levels for installed machinery, engineering systems and equipment. This statement is to detail how the shock policy has been applied and is to include how the specified shock levels have been accommodated within the design.
(c) List of shock captive equipment identifying name, system/function, location, intended shock qualification and mounting arrangements.
(d) List of shock capable equipment identifying name, system/function, location, intended shock qualification and mounting arrangements.
(e) System plans required by other Sections of the Rules are to identify the location of equipment.
(f) Evidence of shock testing.
(g) Shock mount approval documentation.
(h) In cases where numerical modelling and analysis have been carried out, the following supporting information should be submitted as applicable:
    (i) Reference to a recognised and validated calculation procedure and software used.
    (ii) Evidence of software verification and validation.
    (iii) A description of the modelling.
    (iv) A summary of analysis parameters including properties and boundary conditions.
    (v) Details of the loading conditions and the means of applying loads.

(vi) Details of acceptance criteria and their derivation.

(vii) A comprehensive summary of calculation results. Sample calculations should be submitted where appropriate.

In general, submission of large volumes of input and output data associated with such programs as finite element analysis will not be necessary unless requested by LR. The responsibility for error-free specification and input of program data and the subsequent correct transposition of output rests with the designer.

3.3.11 **Underwater signature arrangements.** Where the underwater signature requirements for the ship and propulsion system have been specified, a design statement together with plans and particulars are to be submitted for information. *See Vol 2, Pt 1, Ch 3, 4.10 Guidance for underwater signature* for underwater signature guidance.

3.3.12 **Electromagnetic compatibility.** A test plan in accordance with Clause 5 of IEC 60533 for electromagnetic compatibility is to be submitted for information. *See Vol 2, Pt 1, Ch 3, 4.13 Electromagnetic compatibility (EMC)* for EMC requirements.

3.3.13 **Fin stabilisers.** Where fin stabiliser systems are fitted, the following details are to be submitted:

(a) A System Design Description that details the stabiliser performance in terms of a specified roll angle that is not to be exceeded by more than a stated percentage of rolls in a specified wave environment (*see Vol 1, Pt 5, Ch 2, 2.3 Wave environment*) at a specified ship speed and heading. The performance is to be specified and is to recognise the requirements for ship-based operations, such as flight operations and replenishment at sea (RAS) systems, in terms of sea-keeping and platform heel/trim conditions, and the requirements of *Vol 2, Pt 1, Ch 3, 4 Operating conditions* regarding operating conditions as applicable. Details of any secondary function of the fin stabiliser to induce ship roll, for example routinely to test the fin stabiliser system (against its own induced roll), to facilitate weapon systems testing and to support CBRN Protection pre-wetting systems, are also to be included in the System Design Description.

(b) Plans of all load bearing, torque transmitting components and hydraulic pressure retaining parts of the fin stabiliser system together with proposed rated torque, all relief valve settings and scantlings.

(c) Schematic plans of the hydraulic system(s), together with pipe material, relief valves and working pressures.

(d) Details of safety and control and electrical engineering arrangements.

(e) Material specifications for components identified in (b).

(f) Details of proposed testing and sea trials.

(g) Details of any limits of operation for stabilisation and induced forced roll, e.g. sea states, ship speed, roll amplitude and periodicity limitations.

3.3.14 **Machinery spaces and enclosures.** Evidence is to be submitted demonstrating the suitability of the fire-extinguishing arrangements for a machinery space or enclosure as required by *Vol 2, Pt 1, Ch 3, 5.13 Fire detection, alarm and extinguishing arrangements 5.13.2*. The submission is to identify all standards applied in support of the proposed arrangements. The location of equipment, the degree of protection provided by the equipment itself, and the damage control and fire-fighting requirements in the specified fire safety standard are to be taken into account in determination of the suitability of the fire extinguishing arrangements.

3.3.15 **Schedule of testing and trials.** Schedules of testing machinery at the manufacturers, pre-sea trial commissioning and sea trials are to be submitted to LR and agreed before commencement of testing and trials. The testing and trials schedules are to identify all modes of ship and machinery operation and the sea trials are to include typical port manoeuvres under all intended operating modes. Reference is also made to the following Rules:

- *Vol 1, Pt 3, Ch 5, 8 Windlass and capstan design and testing* - Windlass & capstan trials
- *Vol 2, Pt 1, Ch 3, 15 Steering systems* - Steering systems
- *Vol 2, Pt 1, Ch 3, 16 Sea trials* - Sea trials
- *Vol 2, Pt 9, Ch 11, 1 Testing and trials* - Testing and trials
- *Vol 2, Pt 9, Ch 1, 6 Integrated computer control - ICC notation* - Control engineering trials

Testing and trials are to be witnessed by an LR Surveyor unless an alternative arrangement is agreed in writing prior to the trials by the Surveyor. Reports of testing and trials are to be submitted to an LR Surveyor after completion.

3.3.16 **Machinery operation.** For mobility and ship type category engineering systems, the equipment/machinery manufacturer's instructions for installation and operation of lubricating and hydraulic oil systems are to be made available to the LR surveyors attending trials/testing/commissioning. The instructions should include information that may affect the safety and reliability of the equipment covering requirements for operating environment, monitoring arrangements, cleanliness, filter arrangements, oil change intervals and precautions to be taken at start-up, in operation and during prolonged periods of shutdown.

3.3.17 **Operation of machinery outside its recommended continuous operating design envelope**. Where equipment and machinery installed in mobility and ship type engineering systems may be required to operate for continuous periods outside its recommended continuous operating design envelope, details of the intended operating conditions, time intervals and frequency of use together with documentary evidence indicating the suitability of the design and any limitations under these conditions are required to be submitted. Arrangements may include time alongside manoeuvring, close-down and other military operations or trials. The following items of machinery and equipment are to be considered:

(a) Prime mover(s);
(b) Gearbox(s);
(c) Steering systems;
(d) Bearings;
(e) Couplings;
(f) Vibration dampers;
(g) Shafting and related power and propulsion transmission items;
(h) Other items of machinery and equipment in mobility and ship type engineering systems as identified in the specified standards and agreed by the Owner. The manufacturer's requirements and recommendations for operation and maintenance are to be addressed with provision as necessary of documentation such as manuals and warnings with particular reference to lubrication and cooling systems and any predicted adverse effects e.g. fouling. As far as practicable, the specification, selection and arrangements of machinery and equipment are to be agreed between the Shipbuilder and the Owner for foreseeable operating conditions.

3.3.18 **Training and drill regimes**. Where training and testing regimes for machinery capability and availability, reversionary modes of operation and breakdown drills have been identified by the Owner, full details of the intended regimes are required to be submitted in order to ascertain that the reliability of the machinery and associated systems is not significantly affected. The following are to be considered as applicable and included in the operating and maintenance manuals:

(a) Machinery repair breakdown drills;
(b) Post up-keep trials/Routine assessment trials;
(c) Simulating fault conditions;
(d) Rapid ship manoeuvres;
(e) Electrical equipment and system configuration drills;
(f) Damage control and work-up exercises. As far as practicable, the specification, selection and arrangements of machinery and equipment are to be agreed between the Shipbuilder and Owner for foreseeable training and drill regimes.

3.4 System operational concept

3.4.1 The purpose of this sub-Section is to ensure that LR is provided with all the necessary information at the whole ship system-level to perform design appraisal activities at sub-system and equipment level required by these Rules.

3.4.2 A System Operational Concept document is to be submitted, detailing the design intent and operational modes for complex systems which contain multiple sub-systems and significant items of equipment (e.g. Prime movers, propulsion devices, etc.). Examples of systems requiring the submission of a System Operational Concept include, but are not limited to:

- Propulsion (or Power and Propulsion for integrated systems).
- Electrical Power Generation and Distribution.
- Platform Management System.
- Replenishment at Sea (**RAS**) notation.
- Fire Protection (**FIRE**) notation.

3.4.3 The System Operational Concept is to include the following information, as appropriate to the system:

- Reference to the relevant requirements derived from the Concept of Operations;
- Operating modes and philosophy, including reversionary and emergency modes recognising the operational and manning philosophy for the vessel;
- Describe the designer’s intent and the criticality of particular system features or equipment (with particular reference to those elements required to maintain Mobility and/or Ship Type systems and those installed for capability only);
- Justify non-compliances with the Rules due to the system design and functionality (e.g. black start requirements applied to designated engines only);
- Information required to be included by the individual Chapters.

3.4.4 For ships without complex systems (e.g. single or dual engine installation), the System Operational Concept can be combined with the appropriate System Design Description, *see Vol 2, Pt 1, Ch 3, 3.5 System design description*.

3.4.5 The System Operational Concept documents are to be agreed between the designer and Owner. LR may accept alternative documents where these provide the information which would be included within the System Operational Concept. In such cases the relevant sections providing the information required to provide equivalence with the System Operational Concept are to be identified.

3.5 System design description

3.5.1 The requirements of this sub-Section aim to ensure that LR is provided with sufficient information at the sub-system and equipment level in order to undertake the design appraisal activities required by these Rules.

3.5.2 A System Design Description document is to be submitted to detail the system's sub-system or equipment capability and functionality under all normal and reasonably foreseeable abnormal operating and fault conditions. Examples of systems/ equipment requiring the submission of a System Design Description include but are not limited to:

- Diesel Engines.
- Water jet systems.
- Piping systems.
- HVAC systems.
- Refrigeration Machinery (**PRM**) notation.

3.5.3 The System Design Description is to include the following information, as appropriate to the system:

- Where appropriate, reference to the related Concept of Operations and/or System Operational Concept document;
- Operating modes and philosophy including reversionary and emergency modes recognising the operational and manning philosophy for the vessel;
- System parameters (capacity, power, discharge rate, etc.);
- System redundancy;
- Degraded performance under extreme operating conditions;
- Information required for inclusion in the System Design Description by individual Chapters.

3.5.4 The System Operational Concept documents are to be agreed between the designer and Owner. LR may accept alternative documents where these provide the information which would be included within the System Operational Concept. In such cases the relevant sections providing the information required to provide equivalence with the System Operational Concept are to be identified.

■ *Section 4*
Operating conditions

4.1 Availability for operation

4.1.1 The design and arrangement is to be such that the machinery can be started and controlled on board ship, without external aid, so that operating conditions can be maintained.

4.1.2 Installed machinery is to be capable of operating at defined power ratings with a range of fuels specified by the manufacturer and agreed by the Owner.

4.1.3 Smoke and emission levels from machinery exhaust systems are to be in accordance with those specified by the manufacturer and agreed by the Owner over the full operating range.

4.1.4 Installed machinery is to be capable of operating and being maintained in accordance with the manufacturer's instructions as required by *Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.6* and *Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.16*.

4.1.5 Installed machinery is to be capable of operating satisfactorily in accordance with the manufacturer's stated operating conditions within an operational envelope specified for the ship by the Owner and agreed by the manufacturer/system designer, *see Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.17*. The optimum operational envelope is where machinery and

equipment is operated to provide its best performance without causing undue wear or deterioration that could affect its operational reliability.

4.1.6 Installed machinery is to be capable of operating satisfactorily in accordance with the manufacturer's stated operating conditions within defined training and drill regimes specified by the Owner and agreed by the shipyard and machinery/equipment manufacturer, *see Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.18*.

4.2 Fuel oil

4.2.1 The flash point (closed-cup test) of fuel oil for use in naval ships classed for unrestricted service is, in general, to be not less than 60°C.

4.2.2 The use of fuel having a lower flash point than specified in *Vol 2, Pt 1, Ch 3, 4.2 Fuel oil 4.2.1*, as applicable, may be permitted provided that such fuel is not stored in any machinery space and the arrangements for the complete installation are specially approved *See Vol 2, Pt 7, Ch 4 Aircraft/Helicopter/Vehicle Fuel Piping and Arrangements*

4.3 Power ratings

4.3.1 In the Chapters where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are to be derived from the following:

- For main propelling machinery, the maximum shaft power and corresponding revolutions per minute giving the maximum torque for which the machinery is to be classed.
- For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute which will be used in service.

4.4 Ambient reference conditions

4.4.1 The rating for classification purposes of main and auxiliary machinery intended for installation in Mobility or Ship Type systems in naval sea-going ships to be classed for unrestricted (geographical) service is to be based on:

- A total barometric pressure of 1000 mb
- An engine room ambient temperature or suction air temperature of 45°C.
- A relative humidity of 60 per cent.
- Sea-water temperature or, where applicable, the temperature of the charge air coolant at the inlet of 32°C.

Note The manufacturer is not expected to provide simulated ambient reference conditions at a test bed.

4.4.2 In the case of a naval ship to be classed for restricted service, the rating is to be suitable for the temperature conditions associated with the geographical limits of the restricted service.

4.5 Ambient operating conditions

4.5.1 Main and auxiliary machinery and equipment in Mobility or Ship Type systems are to be capable of operating satisfactorily under the conditions shown in *Table 3.4.1 Ambient operating conditions*.

Table 3.4.1 Ambient operating conditions

Air		
Installations, components	Location, arrangement	Temperature range (°C)
Machinery and electrical installations	In enclosed spaces	0 to +45, *see* Note 1
	On machinery components, boilers, In spaces subject to higher and lower temperatures	According to specific local conditions, *see* Note 2
	On the open deck	–25 to +45, *see* Note 1
Water		
Coolant		Temperature (°C)

Sea-water or charge air coolant inlet to charge air cooler	–2 to +32, *see* Note 1
Note 1. For ships intended to be classed for restricted service, a deviation from the temperatures stated may be considered.	
Note 2. Details of local environmental conditions are stated in Annex B of IEC 60092: *Electrical installations in ships – Part 101: Definitions and general requirements*.	

4.5.2 Where it is intended to allow for operation in ambient temperatures outside those shown in *Table 3.4.1 Ambient operating conditions*, the permissible temperatures and associated periods of time are to be specified by the manufacturer and agreed by the Owner. Engineering systems should retain a continuous level of functional capability under these conditions and any level of degraded performance should be defined. Operation under these circumstances should not be the cause of damage to equipment in the system.

4.6 Inclination of ship

4.6.1 Main and auxiliary machinery in Mobility, Ship Type systems, electrical and emergency equipment are to operate satisfactorily under the conditions as shown in *Table 3.4.2 Inclinations*.

Table 3.4.2 Inclinations

Engineering installations and equipment	Angle of inclination, degrees (*see* Note 1)			
	Athwartship		Fore-and-aft	
	Static(Heel)	Dynamic(Roll)	Static(Trim)	Dynamic(Pitch)
Main and auxiliary machinery in Mobility and Ship Type Systems including electrical equipment	15	±22,5	5 (*see* Note 2)	±7,5
Emergency machinery and equipment including electrical equipment. Switchgear, electrical and electronic appliances (*see* Note 3) and remote control systems	22,5 (*see* Note 4)	±22,5	10	±10
Note 1. Athwartships and fore-and-aft inclination may occur simultaneously.				
Note 2. Where the length of the ship exceeds 100 m, the fore-and-aft static angle of inclination may be taken as 500/L degrees where L = length of ship, in metres.				
Note 3. Up to an angle of inclination of 45 degrees no undesired switching operations or operational changes may occur.				
Note 4. A static damaged condition up to a maximum of 30 degrees may be required by the specified standards.				

4.6.2 The arrangements for lubricating bearings and for draining crankcase and oil sumps of main and auxiliary engines, gearcases, electric generators, motors and other running machinery are to be designed so that they will remain efficient with the ship inclined under the conditions shown in *Table 3.4.2 Inclinations*

4.6.3 Any proposal to deviate from the angles given in *Table 3.4.2 Inclinations* will be specially considered taking into account the type, size and service conditions of the ship.

4.6.4 The dynamic angles of inclination in *Table 3.4.2 Inclinations* may be exceeded in certain circumstances dependent upon ship type and operation. The Shipbuilder is, therefore, to ensure that the machinery is capable of operating under these angles of inclination.

4.7 Power conditions for generator sets

4.7.1 Auxiliary engines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output (kW) and in the case of oil engines and gas turbines, of developing for a short period (15 minutes) an overload power of not less than 10 per cent.

4.7.2 Engine builders are to satisfy the Surveyors by tests on individual engines that the requirements in *Vol 2, Pt 1, Ch 3, 4.7 Power conditions for generator sets 4.7.1*, as applicable, can be complied with, due account being taken of the difference between the temperatures under test conditions and those referred to in *Vol 2, Pt 1, Ch 3, 4.4 Ambient reference conditions 4.4.1*.

Alternatively, where it is not practicable to test the engine/generator set as a unit, type tests (e.g. against a brake) representing a particular size and range of engines may be accepted. With oil engines and gas turbines any fuel stop fitted is to be set to permit the short period overload power of not less than 10 per cent above full rated output (kW) to be developed.

4.8 Astern power

4.8.1 Sufficient astern power is to be provided to maintain control of the ship in all normal circumstances.

4.8.2 Engine builders are to satisfy the Surveyors by tests on individual engines that the requirements in *Vol 2, Pt 1, Ch 3, 4.7 Power conditions for generator sets 4.7.1*, as applicable, can be complied with, due account being taken of the difference between the temperatures under test conditions and those referred to in *Vol 2, Pt 1, Ch 3, 4.4 Ambient reference conditions 4.4.1*. Alternatively, where it is not practicable to test the engine/generator set as a unit, type tests (e.g. against a brake) representing a particular size and range of engines may be accepted. With oil engines and gas turbines any fuel stop fitted is to be set to permit the short period overload power of not less than 10 per cent above full rated output (kW) being developed.

4.9 Military requirements

4.9.1 The Owner is responsible for defining the military requirements relating to the design, construction, testing and installation of machinery and engineering systems.

4.9.2 The following aspects are to be considered for machinery and engineering systems where military requirements are defined:

- Acoustic tiling and other noise reduction techniques.
- Action damage repairs.
- Alternative/back-up supplies.
- Chocking and securing of machinery.
- Design and installation of machinery to withstand shock.
- Electromagnetic compatibility.
- Electromagnetic hazards to personnel.
- Electromagnetic hazards to fuel storage.
- Electromagnetic hazards to ammunition storage.
- Equipment in magazine spaces.
- IR emission.
- Laser hazards.
- Magnetic restrictions.
- Manoeuvring capabilities.
- CBRN capability.
- Noise and vibration for machinery derived noise and vibration signatures.
- Operation of equipment at high ambient temperatures associated with closedown situations.
- Operation of machinery under excessive list and trim conditions.
- Operation of machinery under partial flooding or damage conditions.
- Radar cross-section.
- Reversionary modes of operation.
- Ruggedness of installation and equipment.
- Shutdown and isolation of HVAC systems.
- Smoke clearance requirements.

The foregoing list is not exhaustive and additional aspects may be specified and included by the Owner.

4.9.3 Guidance on design and installation of machinery and engineering systems covering military requirements where they interface with the provisions of classification may be sought from LR for particular installations.

4.9.4 Where a military requirement for disabling automatic control, protection or safety functions for machinery and engineering systems has been defined, the consequences of using the disabling arrangements are to be established and included in the operations procedures and orders provided on board the ship. Details of any disabling arrangements are to be recorded and submitted to LR for consideration in each instance.

4.9.5 Where military mission requirements specify immediate availability of mobility and ship type category engineering systems from cold start conditions, the equipment and arrangements of sub-systems such as lubrication and cooling are to be suitable for operation at a defined level of capability and functionality at stated temperatures.

4.9.6 Systems provided to fulfil military requirements, e.g. weapons or combat systems, are to be arranged such that their operation or failure will not adversely affect the operation of Mobility, Ship Type or Ancillary category systems covered by these Rules.

4.10 Guidance for underwater signature

4.10.1 Where military requirements for underwater signature have been specified, the guidance in *Vol 2, Pt 1, Ch 3, 4.10 Guidance for underwater signature 4.10.2* may be used to assist in achieving the requirements. The Owner is responsible for defining the underwater signature and any requirements in addition to the guidance in this Section. The System Design Description is to include underwater signature levels for the ship and propulsion system, which should be agreed between the designer and Owner, *see Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.11*

4.10.2 Acceptance levels for propulsion and underwater signature are normally specified by the Owner such that propulsive performance and the underwater signature may be determined.

4.10.3 The techniques that may be employed for control of underwater signature are outlined in *Table 3.4.3 Control of underwater signature* for guidance purposes.

Table 3.4.3 Control of underwater signature

Propeller noise	Low resistance hull at required quiet speed. Attention to good inflow into propeller by integrated propeller/hull design. Noise reduced low rpm propeller design
Propeller cavitation	Low resistance hull at required quiet speed. Attention to good inflow into propeller by integrated propeller/hull design. Attention to propeller design and detail Use of high tolerances in manufacture
Propeller induced vibration	Attention to propeller position relative to hull and the interaction between the hull and propeller. Low resistance hull at required quiet speed. Attention to good inflow into propeller by integrated hull/propeller design
Cavitation noise	Attention to good flow to appendages and appendage siting and alignment. Good appendage shapes

4.10.4 The techniques that may be employed for control of underwater signature are:

(a) All machinery should be assessed for its vibration characteristics.
(b) All constructional details connecting machinery to the hull should be assessed for their ability to transmit vibration into the water. If required, suitable vibration isolating machinery, pipe and cable mountings are to be used.
(c) The hull form should be optimised to give efficient performance at the noise quiet speed required in order to obtain the minimum propeller noise signature.
(d) The hull form should be fair and smooth to minimise resistance and flow noise.
(e) Underwater openings should be minimised and attention should be given to the noise characteristics of grilles and shutters.
(f) Attention should be given to the shape, position and alignment of underwater appendages in order to minimise local turbulence, but especially in the flow into the propellers.
(g) Propeller design should be carried out using appropriate noise reduction features.

4.11 Machinery shock arrangements

4.11.1 Where shock requirements for machinery, engineering systems and equipment have been specified, the requirements of this Section are to be met. The Naval Administration is responsible for determining and specifying if these Rules are adequate to meet their requirements and defining any alternative or additional requirements. These Rules may be applied in isolation from or in addition to the requirements of the Shock Enhancement notation, **SH**, *see Vol 1, Pt 4, Ch 2, 5 Underwater explosion (shock)*.

4.11.2 A shock System Design Description, may be specified by the Owner. The System Design Description is to identify the level of shock resistance for installed machinery, engineering systems and equipment and is to address:

(a) Protection of the crew and embarked personnel.

(b) The capability of machinery, equipment and systems to operate after shock loading.

(c) The capability of securing arrangements to retain machinery and equipment captive after shock loading.

(d) The location of machinery/equipment and routing of Mobility and/or Ship Type electrical and piping systems to maintain services in the event of damage due to shock loading.

The application of design and installation of machinery systems for shock resistance is dependent on the Owner requirements detailed in the shock policy. Shock capability may range from full operational capability after repeated shock to that for retaining items captive to avoid injury to personnel.

4.11.3 The actual threat level used in the calculation of performance of the equipment is to be specified by the Owner and will remain confidential to LR.

4.11.4 Where the shock policy requires that shock capability be achieved by separating duplicated items of equipment within a system, with the aim of ensuring that the system remains operational after a shock event, the equipment is to be rugged, and designed to operate in a marine environment. The minimum distance between duplicated items of equipment is to be in accordance with the policy.

4.11.5 The shock performance of individual items of ship's equipment required to operate after shock loading is to be assessed by conducting representative shock tests. For larger items of equipment, a combination of shock tests and numerical modelling may be used, as defined in the System Design Description.

4.11.6 Where equipment shock testing is required, it is to be carried out at a recognised facility in accordance with an acceptable procedure. It is to be ensured that the test arrangements represent the magnitude and direction of loads, and that the loading is applied to the equipment in the configuration in which it will be fitted on board, including shock mounts if applicable.

4.11.7 Equipment previously tested to a particular shock acceleration for another application may be fitted on a vessel with a different shock requirement on condition that the environment in which it is fitted is no more severe than that for which it was tested. In this instance, past test results complemented by a mounting calculation for the proposed arrangements are required.

4.11.8 Where equipment containing electronic components is required to be shock capable, the electronic components are to be tested in accordance with the requirements of *Vol 2, Pt 1, Ch 3, 4.11 Machinery shock arrangements 4.11.6*.

4.11.9 Where equipment is to be installed on shock mounts, the mounts are to be of an approved type and are to meet the requirements of *Vol 1, Pt 4, Ch 2, 5.7 Shock mounts*.

4.11.10 For systems, machinery and equipment which are required to be shock captive or shock capable, non-ductile, brittle, low impact resistance, or high notch sensitivity materials, particularly grey cast iron and cast aluminium are not to be used unless their use can be justified and agreed with the Naval Administration. Materials used, where possible, are to be capable of yielding by approximately 10 per cent before fracture. Whenever possible, the use of glass is to be avoided in machinery, engineering systems and equipment. Where this is not possible, toughened glass is to be used. Where glass is used in tank level gauges, for tanks containing flammable fluids, automatic self-closing valves are to be fitted at the top and bottom of the gauge to prevent the loss of fluid.

4.11.11 For systems, machinery and equipment which are required to be shock captive or shock capable, the use of materials that will be exposed to temperatures below their ductile to brittle transition temperature is to be avoided.

4.11.12 For systems, machinery and equipment which are required to be shock captive or shock capable, stress concentrations in structural arrangements for machinery and equipment are to be avoided and, where possible, welds are to be located away from high stress areas.

4.11.13 For systems, machinery and equipment which are required to be shock capable, overhung and cantilevered components on machinery and equipment are to be avoided where possible.

4.11.14 For systems, machinery and equipment which are required to be shock capable, direct support of connected items of equipment from two or more separate parts of the ship's structure, such as decks and bulkheads, is to be avoided, since differences in response motions at these positions may cause damage.

4.11.15 To minimise relative movement between items of machinery and equipment that require a fixed relationship to each other, wherever possible, they are to be co-located on a common base or frame.

4.11.16 For systems, machinery and equipment which are required to be shock capable, where pipework passes through bulkheads, penetrations of an approved type which have been shock tested are to be used to avoid point loading of the pipes during a shock event. Alternatively, flanged penetrations which are permanently attached to the bulkhead are to be used.

4.11.17 For systems, machinery and equipment which are required to be shock capable, flexible pipework couplings are to be of an approved type which have been shock tested.

4.11.18 Piping runs are to be supported in the region of valves and fittings and supports are to be arranged as close to the elastic centre of the mounting system as possible.

4.11.19 Where required by the shock System Design Description, piping containing flammable fluids passing through compartments of high fire risk are to meet the requirements of *Vol 2, Pt 1, Ch 3, 4.11 Machinery shock arrangements 4.11.16*.

4.11.20 Where equipment is required to remain captive, securing arrangements are to be designed to resist the acceleration/deceleration levels which are associated with the location of the equipment within the ship. The shock captivity levels are to be identified in the System Design Description.

4.11.21 The arrangement of equipment attachment locations is to be such that the height of the centre of gravity above the securing plane is small relative to the span of securing bolts; typically the height of the equipment centre of gravity should be less than one half of the distance between the outermost securing bolts.

4.11.22 For systems, machinery and equipment which are required to be shock captive or shock capable, equipment housing is to be designed to ensure that it is sufficiently strong to withstand the bolt loadings and not allow them to pull through.

4.11.23 For systems, machinery and equipment which are required to be shock capable, the design of machinery trips and breakers is to be such that shock movement cannot trigger them. Also, pivoted parts and link mechanisms, etc. are to be balanced if possible.

4.11.24 For systems, machinery and equipment which are required to be shock capable, adequate clearances are to be allowed between fixed and moving items, equipment and structure and pipes and structure. General clearances are to be approximately 100 mm all round.

4.11.25 For systems, machinery and equipment which are required to be shock captive or shock capable, all fixing lugs are to be closed eyes and not slots. Minimum clearance holes are to be provided for bolts. In general, bolts up to 20 mm diameter are to have a clearance of 1 mm on diameter and for bolts larger than 20 mm, a clearance of 2 mm on diameter.

4.11.26 For systems, machinery and equipment which are required to be shock captive or shock capable, bolted connections are to be tightened to their specified torque limits consistent with the allowable stress in the bolt, typically 2/3 of the yield strength. Lock nuts that lock along the thread length are to be used in preference to lock or star washers.

4.11.27 All connections to equipment that is resiliently mounted are to be capable of accommodating the maximum displacements induced by shock. Resilient mounting of equipment onto equipment that is already resiliently mounted is to be avoided.

4.11.28 For systems, machinery and equipment which are required to be shock capable, flexible hoses and bellows are to have adequate deflection capability in all directions to accommodate relative displacements induced as a result of shock.

4.11.29 Removable items and racks, etc. are to be positively secured when *in situ* with no reliance being made on friction grip or push fits.

4.11.30 Safety equipment (removable escape ladders, fire extinguishers, etc.) is to be secured with quick release arrangements.

4.11.31 Portable items are to have secure stowage or attachments such that they do not become free following shock.

4.11.32 Electrical cables are to be installed to accommodate relative movement under shock.

4.11.33 Where electrical system circuit breakers and fuses are rigidly fastened to the structure, they are to be of an approved shockproof design.

4.11.34 Electrical plug-in components such as printed circuits or relays are to be positively secured in position. Retention by friction is not permitted.

4.11.35 Flexible mounts are not to be degraded by the use of other rigid connections to equipment such as pipework.

4.12 Guidance for CBRN protection, detection and monitoring

4.12.1 Where military requirements to operate under the threat of chemical, biological, radiological and nuclear defence (CBRN) warfare have been specified, the guidance in *Vol 2, Pt 1, Ch 3, 4.12 Guidance for CBRN protection, detection and monitoring 4.12.2* to *Vol 2, Pt 1, Ch 3, 4.12 Guidance for CBRN protection, detection and monitoring 4.12.14* may be used to assist in achieving the requirements. The Owner is responsible for defining the levels of threat, operating periods and for specifying any CBRN Protection requirements in addition to the guidance in this Section. The System Design Description for CBRN Protection of the ship should be agreed between the designer and Owner, *see Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.9*. For hull structure guidance, *see Vol 1, Pt 4, Ch 1, 7 Design guidance for nuclear, biological and chemical defence*.

4.12.2 The prime objectives in the design of CBRN Protection arrangements should address:

(a) Protection of the crew and embarked personnel.

(b) Capability of the ship to operate in close-down conditions when engaged in military missions.

4.12.3 The ship will have a citadel in which the crew can shelter and in particular, ship operations can be managed for long-term close-down conditions. This citadel may be part or all of the ship. Larger citadels may be sub-divided into a number of smaller sub-citadels. The duration of operation with a citadel in use is to be defined in the System Design Description.

4.12.4 The citadel should be designed to provide an over-pressure relative to external ambient conditions such that any leakage of air flows outward from spaces inside the ship. The system design for maintaining over-pressure should recognise degradation of gas-tightness in the ship's structures during operational service and take into account known leakages for the purposes of establishing the required number of air filtration units.

4.12.5 Fresh air required for ventilation purposes should pass through an appropriate level of filtration before entering the citadel. Jalousies fitted at the intakes should be capable of controlling the ingestion of water, particulate and corrosive marine salts to limit degradation of filter units due to moisture carry over. The air filtration units should be capable of providing protection against nuclear, biological and chemical threats defined in the specified standards and should be capable of being cleaned and maintained in accordance with the manufacturer's recommendations. The air filtration systems should be capable of being operated from within the citadel. The maintenance arrangements for air filtration systems should ensure that there is minimum risk of introduction of contaminants into the citadel.

4.12.6 The number, capacity and arrangements of air filtration units should recognise the requirements for operational capability within the ship's zoning policy and air supply requirements to any sub-citadels.

4.12.7 Access to and from the citadel should be via air locks and cleansing stations to decontaminate personnel entering the citadel.

4.12.8 A means of monitoring the level of over-pressure within a citadel should be provided.

4.12.9 Doors, hatches and other closures that are part of the citadel boundary should be clearly marked as such.

4.12.10 All openings into the citadel should be capable of being closed to form a gastight seal. In the case of fluid systems with overboard discharges that are required to be open for operational reasons, these should be fitted with water seals to prevent the ingress of external air. Arrangements should be made to re-circulate air for ventilation/ air conditioning purposes, such as galley air, and where necessary, provide bleed valves such that air may be purged via the air locks/cleansing stations without allowing external air to re-enter the citadel. The arrangements for re-circulation and fresh air intakes should take into account the maximum permitted levels of CO_2 and any other gases/ odours that may prejudice the safety of crew and embarked personnel.

4.12.11 In the case of machinery spaces that are to be kept 'clean' during CBRN states by closures, combustion air should be trunked directly to the prime movers and adequate cooling is to be provided within these spaces to maintain safe equipment operation. Arrangements should be provided to permit engines to breathe as required for full power operational requirements. *See Vol 2, Pt 1, Ch 3, 5.12 Machinery enclosures* for requirements for machinery enclosures.

4.12.12 A means of preventing adherence of contamination and for decontamination of the outside of the ship should be provided by pre-wetting/wetting systems. Adequate means of drainage should be provided for pre-wetting/wetting water. The siting of nozzles and drainage arrangements should be arranged to avoid build-up of water and potential ingress of water into air intakes for ventilation and machinery air intakes.

4.12.13 A means of monitoring, indicating and warning of CBRN contamination should be provided.

4.12.14 Nuclear shelter positions for ship's crew and embarked personnel should be identified. These positions should be provided with adequate means of ventilation capable of maintaining the atmosphere with a maximum CO^2 level of 1,5% for a defined period of time.

4.13 Electromagnetic compatibility (EMC)

4.13.1 Propulsion, steering, navigation and other Mobility and/or Ship Type systems, including weapons systems are to be designed and installed such that their performance does not degrade from the manufacturer's specifications as a result of susceptibility to electromagnetic interference generated during both normal operation and during military activities.

4.13.2 An EMC test plan is to be established, an EMC analysis carried out and a test report produced in accordance with the requirements and guidelines of IEC 60533 *Electrical Installations in Ships, Electromagnetic Compatibility* or equivalent requirements of the Naval Administration as defined in a specified standard. Regard is to be given to the fact that EMC requirements for systems installed on board naval ships may be more onerous due to the high concentration of electronic equipment, transmitters and receivers located in close proximity. Details are to be submitted for appraisal.

4.13.3 Systems are to comply with the emission limits and minimum immunity requirements of the specified standards. This may require systems complying with emissions and immunity requirements of IEC 60533 *Electrical Installations in Ships, Electromagnetic Compatibility* to be subjected to additional testing in order to demonstrate the requirements of the specified standards are satisfied unless the EMC analysis clearly identifies such testing to be unnecessary. Details are to be submitted for appraisal.

4.14 Machinery interlocks

4.14.1 Interlocks are to be provided to prevent any operation of engines, turbines or applicable auxiliary machinery under conditions that could hazard the machinery or personnel. These are to include 'turning gear engaged', 'low lubricating oil pressure', where oil pressure is essential for the prevention of damage during start up, 'shaft brake engaged' and where machinery is not available due to maintenance or repairs. The interlock system is to be arranged to 'fail safe'.

4.14.2 In the case of machinery with manual turning gear which is not permanently attached, warning devices or notices may be provided as an alternative to interlocks as required by *Vol 2, Pt 1, Ch 3, 4.14 Machinery interlocks 4.14.1*.

4.15 Stopping of machinery

4.15.1 Diesel engines, gas and steam turbines, other prime movers, Mobility systems and Ship Type systems are to be provided with a means of emergency stop, capable of being activated at a position outside the compartment in which the machinery is located. The arrangements are to be fully independent of control and alarm systems, and are to ensure a safe and controlled shutdown of machinery. Where such arrangements depend upon programmable electronic equipment, they are to comply with the relevant requirements in *Vol 2, Pt 9, Ch 8, 5.4 Additional requirements for Mobility category and safety critical systems*

4.15.2 Emergency stops are to be designed to minimise the risk of accidental or unauthorised operation.

4.16 Control of rotating systems

4.16.1 An effective means of setting and adjusting the rotation speed of each complete rotating system (e.g. prime mover, gearing, shafting, alternator and propeller) to defined operating performance requirements is to be provided. The means and arrangements for adjusting the speed of rotation are to recognise any requirements for the avoidance of running in barred speed range(s).

4.16.2 All prime movers are to be provided with an efficient governor arrangement that is capable of controlling the prime mover's set speed within defined limits when subject to load changes. The performance of governors is to recognise the rotating system's specification of capability during normal, emergency and reversionary modes of operation. For power train systems, the inertia of components and associated requirements for speed control of the prime mover are to be addressed. *See Vol 2, Pt 2, Ch 1 Reciprocating Internal Combustion Engines*, *Vol 2, Pt 2, Ch 2 Gas Turbines* and *Vol 2, Pt 2, Ch 3 Steam Turbines* for the respective performance requirements of governors fitted to diesel engines, gas turbines and steam turbines.

4.16.3 The arrangements for control of rotating systems are to comply with *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems* as applicable and are to be such that failure in any item of equipment in the control system does not cause a hazard to the operation of the prime mover. The arrangements are to comply with the requirements of *Vol 2, Pt 1, Ch 3, 4.16 Control of rotating systems* as applicable.

4.17 Survey and refit

4.17.1 Arrangements are to be provided for the discharge of fuels and lubricating oils from the ship to a safe off ship facility where operational requirements necessitate system cleaning and refit.

4.18 Electromagnetic hazards

4.18.1 All equipment, operating and observation positions are, as far as is practicable, to be sited clear of sources of electromagnetic energy such as radars, communication transmitters or lightning conductors.

4.18.2 Where sources of electromagnetic energy or the swept beam of radar aerials are in close proximity to equipment operating and observation positions, suitable warning notices and markings are to be provided to draw attention to the potential hazards.

4.19 Flexible hose and bellows expansion piece registers

4.19.1 Flexible hoses and bellows expansion piece units are life limited and a Register of such units is to be established and maintained for all units installed on board where failure may result in any of the following:

(a) Fire spread.
(b) Flooding that could lead to the loss of any compartment.
(c) Loss of availability of a mobility or ship type system.
(d) Danger to personnel from release of stored energy.

4.19.2 The following information is to be included in the Register:

(a) Equipment designation and location on ship.
(b) Purpose.
(c) Hose specification including end fittings.
(d) Date of manufacture and cure date in the case of rubber units.
(e) Date of installation.
(f) Date of pressure/installation testing.
(g) Routine inspection interval.
(h) Pressure testing.
(i) Due for renewal.

A typical Flexible Hose Register format is shown in *Table 3.4.4 Typical Flexible Hose Register*.

Table 3.4.4 Typical Flexible Hose Register

Flexible hose register				
System			Length	
Equipment			Nominal bore	
Position			Offset angle between elbow and fittings	
End fitting 1			End fitting 2	
Purpose			Max.. working pressure	
Specification			Hose test pressure	
Manufacturer's part No.	Cure date	Date fitted	Date for renewal	Inspection, test, change date and remarks

4.19.3 Flexible hoses and bellows expansion pieces are to comply with the requirements of *Vol 2, Pt 7, Ch 1, 13 Flexible hoses* and *Vol 2, Pt 7, Ch 1, 14 Expansion pieces* as applicable and should be labelled in order to provide a clear trace between the Register and equipment.

4.19.4 A Naval Authority may require the scope of a flexible hose or expansion bellows piece Register for purposes other than those detailed in *Vol 2, Pt 1, Ch 3, 4.19 Flexible hose and bellows expansion piece registers 4.19.1*.

Section 5
Machinery space arrangements

5.1 Machinery spaces

5.1.1 Machinery spaces of category A are those spaces and trunks to such spaces which contain:

(a) internal combustion machinery used for main propulsion; or
(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power of not less than 375 kW; or
(c) any oil-fired boiler or fuel oil unit.

5.1.2 Machinery spaces are all machinery spaces of Category A and all other spaces containing propulsion machinery, boilers, fuel oil units (defined in *Vol 2, Pt 1, Ch 3, 5.1 Machinery spaces 5.1.3*), steam and internal combustion engines, generators and major electrical machinery, oil filling stations, refrigerating, stabilising, ventilation and air-conditioning machinery, and similar spaces and trunks to such spaces.

5.1.3 A fuel oil unit is the equipment used for the preparation of fuel oil for delivery to an oil-fired boiler, or equipment used for the preparation for delivery of heated oil to an internal combustion engine, and includes oil pressure pumps, filters and heaters dealing with oil at a pressure of more than 0,18 N/mm^2.

5.1.4 Aluminium is not to be used for the crowns or casings of Category A machinery spaces. Where the hull is constructed of aluminium or composite material, consideration will be given to the use of aluminium for the crown or casings for such spaces where the fire safety issues relating to the use of aluminium have been addressed to the satisfaction of LR.

5.1.5 Windows are not to be fitted in machinery space boundaries. However, this does not preclude the use of glass in control rooms within the machinery space.

5.1.6 Machinery space skylights, where fitted, are not to contain glass.

5.1.7 In addition, the requirements of *Vol 1, Pt 3, Ch 2, 6 Machinery space arrangements* are to be complied with.

5.2 Accessibility

5.2.1 Accessibility, for attendance and maintenance purposes, is to be provided in all spaces for machinery and engineering systems and equipment.

5.2.2 Removal routes for items of machinery and equipment are to be established where routine removal of major items of equipment is envisaged.

5.3 Machinery fastenings

5.3.1 Bedplates, thrust seatings and other fastenings are to be of robust construction, and the machinery is to be securely fixed to the ship's structure to the satisfaction of the Surveyor. For NS3 type ships or where specified, the arrangement is to be such that it is sufficient to restrain the dynamic forces arising from vertical and horizontal acceleration appropriate to the intended service, *see Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.5* and *Vol 2, Pt 1, Ch 3, 5.4 Collision load*.

5.3.2 Machinery may be installed on rafts of rigid construction and these are to be of robust construction to ensure that alignment is maintained under all conditions of ship motion. The rafts are to be securely fixed to the ship's structure.

5.4 Collision load

5.4.1 Unless an accurate analysis of the collision load is submitted and found acceptable by LR, the collision load is to be determined from:

$$g(\text{collision}) = 1,2\frac{\mathrm{P}_{\text{coll}}}{\Delta\,\mathrm{g}}$$

where the load P_{coll} is taken as the lesser of:

$$P_{\text{coll}} = 460\,(M\,C_L)^{2/3}\,(E\,C_H)^{1/3}\ \text{kN}$$

$$P_{\text{coll}} = 9000\,M\,C_L\,[C_H\,(T+2)]^{1/2}\ \text{kN}$$

where

C_H = a factor given in *Table 3.5.1 Factor C_H*

C_L = $\dfrac{(165 + L_{WL})}{245}\left(\dfrac{L_{WL}}{80}\right)^{0,4}$

D = ship depth, in metres, from the underside of keel amidships to the top of effective hull girder

E = $0{,}5\Delta V^2$ kNm

H_T = minimum height, in metres, from tunnel or wet-deck bottom to the top of effective hull girder for catamarans and surface effect ships

= D for air cushion vehicles

L_{WL} = ship waterline length, in metres

M = 1,3 for high tensile steel

= 1,0 for aluminium alloy

= 0,95 for mild steel

= 0,8 for fibre reinforced plastics

T = buoyancy tank clearance to skirt tip, in metres, (negative) for ACVs

= lifted clearance from keel to water surface, in metres, (negative) for hydrofoils

= ship draught to the underside of keel amidships, in metres, for all other ships

V = operational speed of ship, in m/s

g = gravitational acceleration = 9,806 m/s^2

Δ = ship displacement, to be taken as the mean of the lightweight and maximum operational weight, in tonnes.

Table 3.5.1 Factor C_H

Factor C_H	Catamarans, SES	Mono-hulls, H'Foils	ACVs
C_H	$\dfrac{T+2+f(D/2)}{2D}$	$\dfrac{T+2+f(D/2)}{2D}$	$\dfrac{f}{4}$
where			
f = 0 for	$T + 2 < D - H_T$	$T + 2 < D$	—
f = 1 for	$D > T + 2 \geq D - H_T$	$T + 2 \geq D$	$H_T > 2$
f = 2 for	$T + 2 \geq D\,M$	—	$H_T \leq 2$

5.5 Resilient mountings

5.5.1 The dynamic angles of inclination in *Table 3.4.2 Inclinations* may be exceeded in certain circumstances dependent upon ship type and operation. The Shipbuilder is, therefore, to ensure that the vibration levels of flexible pipe connections, shaft couplings and mounts remain within the limits specified by the component manufacturer for the conditions of maximum dynamic inclinations to be expected during service, start-stop operation and the natural frequencies of the system. Due account is to be taken of any creep that may be inherent in the mount.

5.5.2 Limit stops are to be fitted as necessary to ensure that manufacturers' limits are not exceeded. Suitable means are to be provided to accommodate the propeller thrust.

5.5.3 Mounts are to be shielded from the possible detrimental effects of oil and, where appropriate, paint and other contaminants.

5.6 Resin chocks

5.6.1 Synthetic resin compounds as materials for chocks under machinery where alignment is important are to be of a type accepted by LR.

5.6.2 The use of resin for chocking gas turbine casings or similar high temperature applications is not acceptable.

5.6.3 Materials for chocking are to be approved for the maximum ambient operating temperature of the space in which they are installed.

5.6.4 Where the ship has specified military requirements that include design and installation of machinery to withstand shock, the resin is to be approved for this application.

5.7 Ventilation

5.7.1 All spaces including engine and pump spaces, where flammable or toxic gases or vapours may accumulate, are to be provided with adequate ventilation under all conditions.

5.7.2 Machinery spaces are to be ventilated so as to ensure that when machinery or boilers therein are operating at full power in all weather conditions, including heavy weather, a sufficient supply of air is maintained to the spaces for the safety of personnel and the operation of machinery.

5.7.3 The selection and arrangements of machinery and associated equipment are to minimise the emission of noxious substances into machinery spaces.

5.8 Fire protection

5.8.1 All surfaces of machinery where the surface temperature may exceed 220ºC and where impingement of flammable liquids may occur are to be effectively shielded to prevent ignition. Where insulation covering these surfaces is oil-absorbing or may permit penetration of oil, the insulation is to be encased in steel or equivalent.

5.9 Means of escape

5.9.1 Except as permitted in *Vol 2, Pt 1, Ch 3, 5.9 Means of escape 5.9.2*, two means of escape are to be provided from each machinery space of Category A. In particular, one of the following provisions are to be complied with:

(a) Two sets of steel ladders as widely separated as possible leading to doors in the upper part of the space similarly separated and from which access is provided to the open deck. In general, one of these ladders shall provide continuous fire shelter from the lower part of the space to a safe position outside the space. The shelter is to be of steel, insulated, where necessary and provided with a self-closing steel door. The shelter will not be required if, due to the special arrangement or dimensions of the machinery space, a safe escape route from the lower part of the space is provided.

(b) One steel ladder leading to a door in the upper part of the space from which access is provided to the open deck and additionally, to the lower part of the space and in a position well separated from the ladder referred to, a steel door capable of being operated from each side and which provides access to a safe escape route from the lower part of the space to the open deck.

Alternative arrangements in accordance with the requirements as specified by the Naval Administration may also be acceptable.

5.9.2 Where specified and agreed by the Naval Administration, in a NS3 category ship, one of the means of escape required in *Vol 2, Pt 1, Ch 3, 5.9 Means of escape 5.9.1* may not be required with due regard being paid to the dimension and disposition of the upper part of the space.

5.9.3 When access to any machinery space of Category A is provided at a low level from an adjacent shaft tunnel, there is to be provided in the shaft tunnel, near the watertight door, a light steel fire-screen operable from each side.

5.9.4 From machinery spaces other than those of Category A, escape routes are to be provided having regard to the nature and location of the space and whether persons are normally employed in the space.

5.9.5 Lifts are not to be considered as forming one of the required means of escape.

5.10 Communications

5.10.1 At least two independent means of communication are to be provided between the bridge and engine room control station from which the engines are normally controlled.

5.10.2 One of the two means required by *Vol 2, Pt 1, Ch 3, 5.10 Communications 5.10.1* shall visually indicate the order and response, both at the engine room control station and on the bridge.

5.10.3 At least one means of communication is to be provided between the bridge and any other control position(s) from which the propulsion machinery may be controlled.

5.10.4 At least two independent means of communication are to be provided between the main and emergency switchboards.

5.11 Personnel safety

5.11.1 All moving parts of machinery are to be provided with suitable railings and/or guards to prevent injury to personnel.

5.11.2 Protection is to be provided to prevent injury from hot surfaces, i.e. by suitable lagging or guards.

5.11.3 Assemblies incorporating pre-loaded springs are to be engineered such that spring forces can be released in a controlled and safe manner during the removal and/or disassembly process.

5.11.4 Open ends from relief valve pressure release pipes are to be arranged so that any discharge is directed away from positions where personnel might reasonably be expected to be. If relief pipes cross citadel boundaries, the relief valves are to relieve through sealed tundishes able to withstand the citadel over-pressure.

5.11.5 Sufficient deck plates, platforms and handholds are to be fitted to provide safe access to all parts of the machinery and ensure safe passageway between machinery and adjacent equipment.

5.11.6 Materials used in the construction of machinery and installation of engineering systems are not to be a recognised hazard to personnel. This includes the prohibition of asbestos.

5.11.7 Means are to be provided for automatically giving audible warning of the release of fire-extinguisihing medium into any space in which personnel normally work or to which they have access, *see also Vol 2, Pt 9, Ch 9, 5.8 Fire extinguishing media release 5.8.1*

5.12 Machinery enclosures

5.12.1 Where machinery is installed within enclosures, the requirements of *Vol 2, Pt 1, Ch 3, 5.12 Machinery enclosures 5.12.2* and *Vol 2, Pt 1, Ch 3, 5.13 Fire detection, alarm and extinguishing arrangements* are to be complied with.

5.12.2 Enclosures are to be treated as unattended machinery spaces and comply with the relevant Rules for such spaces and installed equipment.

5.12.3 Enclosures are, as far as reasonably practicable, to be gastight with flexible sealing arrangements between air induction, exhaust and ventilation systems.

5.12.4 The arrangements are to prevent contamination of the machinery space in an CBRN environment.

5.12.5 Enclosures are to be constructed to form a suitable fire boundary.

5.12.6 An access door, adequate internal lighting and observation windows, with suitable fire rating, are to be located to afford a clear view of both sides of the equipment within the enclosure.

5.12.7 Suitable means of drainage of any liquids which may accumulate are to be provided without compromising the citadel.

5.12.8 Enclosures are to be suitably ventilated and designed to maintain all components within their safe working temperature under all operating conditions. The ventilation system is to be independent from the machinery space ventilation arrangements and provided with suitable closing devices for fire control purposes.

5.12.9 Enclosures are to be provided with a means to enable gas purging with a portable fan in addition to the fixed ventilation system.

5.12.10 Means are to be provided to monitor the enclosure air temperature and differential pressure.

5.13 Fire detection, alarm and extinguishing arrangements

5.13.1 Machinery spaces and enclosures are to be provided with fire detection, alarm and extinguishing systems in accordance with the fire safety arrangements required by the Regulations in *Vol 1, Pt 1, Ch 2, 1.1 Framework of Classification 1.1.9* For

unattended machinery spaces a fire detection system in accordance with *Vol 2, Pt 9, Ch 1, 4.5 Fire detection alarm system* is to be fitted.

5.13.2 The design of fire extinguishing arrangements in any machinery space or enclosure are to take the following into consideration:

(a) The flammable materials and potential sources of ignition within the space or enclosure;
(b) any need for machinery and equipment to remain operational during operation of the fire extinguishing arrangements;
(c) the need for machinery and equipment to continue to function normally following operation of the fire extinguishing arrangements; and
(d) any need for personnel to enter or remain within the space or enclosure during operation of the fire extinguishing arrangements.

In spaces where electrical equipment is located, consideration is to be given to providing separate enclosures where appropriate. *See also Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.14*.

5.14 Location of emergency installations

5.14.1 Emergency sources of electrical power, fire pumps, bilge pumps except those specifically serving the spaces forward of the collision bulkhead, any fixed fire-extinguishing system and other emergency installations which are essential for the safety of the ship, except anchor windlasses, shall not be installed forward of the collision bulkhead.

■ *Section 6*
Reciprocating internal combustion engines

6.1 Design and testing

6.1.1 For details of design requirements, *see Vol 2, Pt 2, Ch 1 Reciprocating Internal Combustion Engines*.

6.1.2 For details of materials and component testing requirements, *see Vol 2, Pt 2, Ch 1, 3 Materials and components*.

6.1.3 For details of engine type testing requirements, *see Vol 2, Pt 2, Ch 1, 12 Type Testing – General* and LR's Type Approval Test Specification No. 4 – *Type Testing of Reciprocating Internal Combustion Engines and Associated Ancillary Equipment.*

6.2 Construction and welding

6.2.1 Welding of engine structures is to be in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

6.2.2 On completion of welding and stress relief heat treatment, welds are to be examined. Welds in transverse girder assemblies are to be crack detected by an approved method. Other joints are to be similarly tested if required by the Surveyors.

6.2.3 Forgings and castings are to be examined at the manufacturer's works.

■ *Section 7*
Turbochargers

7.1 Design and testing

7.1.1 For details of design requirements, *see Vol 2, Pt 2, Ch 1 Reciprocating Internal Combustion Engines*.

7.1.2 For details of testing requirements, *see Vol 2, Pt 2, Ch 1, 11 Turbochargers*.

■ *Section 8*
Gas turbines

8.1 Design

8.1.1 For details of design requirements, *see Vol 2, Pt 2, Ch 2 Gas Turbines*.

8.2 Construction under survey

8.2.1 All gas turbine units intended for installation in a ship classed or intended to be classed with LR are to to be constructed in accordance with LR's Quality Assurance Scheme for Machinery, *see Vol 2, Pt 1, Ch 1, 8 Quality assurance scheme for machinery*.

8.3 Dynamic balancing

8.3.1 All compressor and turbine rotors as finishedbladed and complete with all relevant parts such as halfcouplings, are to be dynamically balanced in accordance with the manufacturer's specification in a machine of sensitivity appropriate to the size of rotor.

8.4 Hydraulic testing

8.4.1 Where design permits, casings are to be tested to a hydraulic pressure equal to 1,5 times the highest pressure in the casing during normal operation, or 1,5 times the pressure during starting, whichever is the higher. For test purposes, if necessary, the casings may be subdivided with temporary diaphragms for distribution of test pressure. Where the operating temperature exceeds 300°C, the test pressure is to be suitably corrected.

8.4.2 Where hydraulic testing is impracticable, nondestructive tests by ultrasonic or radiographic methods are to be carried out on the entire circumference of all casing parts with satisfactory results. Where ultrasonic tests have been carried out, the manufacturer is to provide documentary evidence that ultrasonic examination has been carried out by an approved operator and that there were no indications of defects which could be expected to have a prejudicial effect on the operational performance of the gas turbine.

8.4.3 The shell and tube arrangement of intercoolers and heat exchangers are to be tested to 1,5 times their maximum working pressure.

8.5 Overspeed tests

8.5.1 Before installation, it is to be satisfactorily demonstrated that the gas turbine is capable of safe operation for five minutes at 5 per cent above the nominal setting of the overspeed protective device, or 15 per cent above the maximum design speed, whichever is the higher.

8.5.2 Where it is impracticable to overspeed the complete installation, each compressor and turbine rotor completely bladed and with all relevant parts such as halfcouplings, are to be overspeed-tested individually at the appropriate speed.

■ *Section 9*
Steam turbines

9.1 Design

9.1.1 For details of design requirements, *see Vol 2, Pt 2, Ch 3 Steam Turbines*

9.2 Stability testing of turbine rotors

9.2.1 All solid forged H.P. turbine rotors intended for main propulsion service where the inlet steam temperature exceeds 400ºC are to be subjected to at least one thermal stability test. This requirement is also applicable to rotors constructed from two or more forged components joined by welding. The test may be carried out at the forge or turbine builders' works:

(a) after heat treatment and rough machining of the forging, or

(b) after final machining, or

(c) after final machining and blading of the rotor.

The stabilising test temperature is to be not less than 28ºC above the maximum steam temperature to which the rotor will be exposed, and not more than the tempering temperature of the rotor material. For details of a recommended test procedure and limits of acceptance, *see Rules for the Manufacture, Testing and Certification of Materials, July 2015*. Other test procedures may be adopted if approved.

9.2.2 Where main turbine rotors are subjected to thermal stability tests at both forge and turbine builders' works, the foregoing requirements are applicable to both tests. It is not required that auxiliary turbine rotors be tested for thermal stability, but if such tests are carried out, the requirement for main turbine rotors will be generally applicable.

9.3 Balancing

9.3.1 All rotors as finished-bladed and complete with half-coupling are to be dynamically balanced to the Surveyor's satisfaction, in a machine of sensitivity appropriate to the size of rotor.

9.4 Hydraulic tests

9.4.1 Manoeuvring valves are to be tested to twice the working pressure. The nozzle boxes of impulse turbines are to be tested to 1,5 times the working pressure.

9.4.2 The cylinders of all turbines are to be tested to 1,5 times the working pressure in the casing, or to 2,0 bar, whichever is the greater.

9.4.3 For test purposes, the cylinders may be subdivided with temporary diaphragms for distribution of test pressures.

9.4.4 Condensers are to be tested in the steam space to 1,0 bar. The water space is to be tested to the maximum pressure which the pump can develop at ship's full draught with the discharge valve closed plus 0,7 bar, with a minimum test pressure of 2,0 bar. Where the operating conditions are not known, the test pressure is to be not less than 3,4 bar, *see Vol 2, Pt 7, Ch 1 Piping Design Requirements*

9.5 Indicators for movement

9.5.1 Indicators for determining the axial position of rotors relative to their casings, and for showing the longitudinal expansion of casings at the sliding feet, if fitted, are to be provided for main turbines. The latter indicators should be fitted at both sides and be readily visible.

9.6 Weardown gauges

9.6.1 Main and auxiliary turbines are to be provided with bridge weardown gauges for testing the alignment of the rotors.

■ *Section 10* Gearing

10.1 Design

10.1.1 For details of design requirements, *see Vol 2, Pt 3, Ch 1 Gearing*

10.2 Construction and welding

10.2.1 Where castings are used for wheel centres, any radial slots in the periphery are to be fitted with permanent chocks before shrinking-on the rim.

10.2.2 Where welded construction is used for the manufacture of wheels and gearcases, welding is to be in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

10.2.3 Welded constructions are to be stress relief heat treated on completion of welding.

10.2.4 Bolted attachments within the gear case are to be secured by locking wire or equivalent means.

10.3 Accuracy of gear cutting

10.3.1 The machining accuracy (Q grade) of pinions and wheels is to be demonstrated. For this purpose, records of measurements are to be available for review.

10.4 Non-destructive testing

10.4.1 Magnetic particle or liquid penetrant testing is to be carried out on the teeth of all surface hardened forgings. This examination may also be requested on the finished machined teeth of through hardened gear forgings.

10.4.2 The manufacturer is to carry out an ultrasonic examination of all forgings where the finished diameter of the surfaces, where teeth will be cut, is in excess of 200 mm, and is to provide LR with a signed statement that such inspection has not revealed any significant internal defects.

10.4.3 On gear forgings where the teeth have been surface hardened, additional test pieces may be required to be processed with the forgings and subsequently sectioned to determine the depth of the hardened zone. These tests are to be carried out at the discretion of the Surveyor, and for induction or carburised gearing, the depth of the hardened zone is to be in accordance with the approved specification. For nitrided gearing, the full depth of the hardened zone, i.e. depth core hardness, is to be not less than 0,5 mm and the hardness at a depth of 0,25 mm is to be not less than 500 Hv.

10.5 Dynamic balancing

10.5.1 All rotating elements such as pinion and wheel shaft assemblies and coupling parts, are to be appropriately balanced.

10.5.2 The permissible residual unbalance, U, is defined as follows:

$$U = \frac{60\text{m}}{R} \text{ x } 10^3 \text{ g mm for } R < 3000$$

$$U = \frac{24\text{m}}{R} \text{ x } 10^3 \text{ g mm for } R > 3000$$

where

m = mass of rotating element, in kg

R = maximum service rev/min of the rotating element.

10.5.3 Where the size or geometry of a rotating element precludes measurement of the residual unbalance, a full speed running test of the assembled gear unit at the manufacturer's works will normally be required to demonstrate satisfactory operation.

10.6 Meshing tests

10.6.1 Initially, meshing gears are to be carefully matched on the basis of the accuracy measurements taken. The alignment is to be demonstrated in the workshop by meshing in the gearbox without oil clearance in the bearings. Meshing is to be carried out with the gears locating in their light load positions and a load sufficient to overcome pinion weight and axial movement is to be imposed.

10.6.2 The gears are to be suitably coated to demonstrate the contact marking. The thickness of the coating to determine the contact marking is not to exceed 0,005 mm. The marking is to reflect the accuracy grade specified and end relief, crowning or helix correction, where these have been applied.

10.6.3 For gears without crowning or helix correction the marking is to be not less than shown in *Table 3.10.1 No load tooth contact marking*.

Table 3.10.1 No load tooth contact marking

ISO accuracy grade	Contact marking area
Q ≤ 5	50% b x 40% h_w + 40% b x 20% h_w

Q ≥ 6	35% *b* x 40% h_w + 35% *b* x 20% h_w
Note 1. Where *b* is the face width and h_w is the working tooth depth.	
Note 2. For spur gears, the values of h_w should be increased by a further 10%	

10.6.4 Where allowance has been given for end relief, crowning or helix correction, the normal shop meshing tests are to be supplemented by tooth alignment traces or other approved means to demonstrate the effectiveness of such modifications.

10.6.5 For gears with crowning or helix correction the marking is to correspond, to the designed no load contact pattern.

10.6.6 A permanent record is to be made of the meshing contact for purpose of checking the alignment when installed on board the craft.

10.6.7 The full load tooth contact marking is to be not less than shown in *Table 3.10.2 Full load tooth contact marking*

Table 3.10.2 Full load tooth contact marking

ISO accuracy grade	Contact marking area
Q ≤ 5	60% *b* x 70% h_w + 30% *b* x 50% h_w
Q ≥ 6	45% *b* x 60% h_w + 35% *b* x 40% h_w
Note 1. Where *b* is the face width and h_w is the working tooth depth.	
Note 2. For spur gears, the values of h_w should be increased by a further 10%	

10.6.8 Where, due to the compactness of the gear unit, meshing tests of individual units cannot be verified visually, consideration may be given to the gear manufacturer providing suitable evidence that the design meshing condition has been attained on units of the same design.

10.6.9 The normal backlash between any pair of gears should not be less than: + 0,1 mm

$$\frac{\mathrm{a}.\,\alpha_{\mathrm{n}}}{9000} + 0,1\ \mathrm{mm}$$

where

α_n = normal pressure angle, in degrees

a = centre distance, in mm.

■ *Section 11*
Shafting systems

11.1 Design

11.1.1 For details of design requirements, *see Vol 2, Pt 3, Ch 2 Shafting Systems*

11.2 Construction

11.2.1 Boring of the sternframe, fitting of the sterntube and bearings and aligning the shafting are to be carried out to a formal traceable procedure.

11.2.2 Before boring the sternframe, the ship's structure should be generally complete to the upper deck and to the engine-room forward bulkhead.

11.3 Shaft bearing clearances

11.3.1 After installation of the screwshaft and any shafting installed in bearings fitted in stern bushes or shaft bearings in 'A' and 'P' brackets, the bearing clearances are to be measured and recorded. The records are to be placed on board.

■ *Section 12* Propellers

12.1 Design

12.1.1 For details of design requirements, *see Vol 2, Pt 4, Ch 1 Propellers*

12.2 Construction and welding

12.2.1 Castings are to be examined at the manufacturer's works.

12.2.2 All finished propellers are to be examined for material defects, and finish, and measured for dimensional accuracy of diameter and pitch. Propeller repairs by welding, where proposed, are to be in accordance with the requirements of *Ch 9, 1 Castings for propellers* of the Rules for Materials.

12.3 Shop tests of keyless propellers

12.3.1 The bedding of the propeller with the shaft is to be demonstrated. Sufficient time is to be allowed for the temperature of the components to equalise before bedding. Alternative means for demonstrating the bedding of the propeller will be considered.

12.3.2 Means are to be provided to indicate the relative axial position of the propeller boss on the shaft taper.

12.4 Shop tests of controllable pitch propellers

12.4.1 The components of controllable pitch propellers are also subject to material tests, as in the case of solid propellers.

12.4.2 Examination of all the major components including dimensional checks, hydraulic pressure testing of the hub and cone assembly and the oil distribution box, where fitted, together with a full shop trial of the completed controllable pitch propeller assembly, is to be carried out.

12.5 Final fitting of keyless propellers

12.5.1 After verifying that the propeller and shaft are at the same temperature and that the mating surfaces are clean and free from oil or grease, the propeller is to be fitted on the shaft under survey. The propeller nut is to be securely locked to the shaft.

12.5.2 Permanent reference marks are to be made on the propeller boss nut and shaft to indicate angular and axial positioning of the propeller. Care is to be taken in marking the inboard end of the shaft taper to minimise stress raising effects.

12.5.3 The outside of the propeller boss is to be hard stamped with the following details:

For oil injection method of fitting, the start point load, in Newtons, and the axial pull-up at 0ºC and 35ºC, in mm. For the dry fitting method, the push-up load at 0ºC and 35ºC, in Newtons.

12.5.4 A copy of the fitting curve relative to temperature and means for determining any subsequent movement of the propeller are to be placed on board.

12.6 Final fitting of keyed propellers

12.6.1 The fit of the screwshaft cone to both the working and any spare propeller is to be carried out under survey. Generally, a satisfactory fit for keyed type propellers should show a light, overall marking of the cone surface with a tendency towards heavier marking in way of the larger diameter of the cone face. The final fit to cone should be made with the key in place.

Section 13
Water jet units

13.1 Design

13.1.1 For details of design requirements, *see Vol 2, Pt 4, Ch 2 Water Jet Systems*.

13.2 Construction and welding

13.2.1 The following components are to be inspected at the manufacturer's works:

- Steering nozzle.
- Reverse bucket.
- Stator impeller.
- Integral bearing.

13.2.2 Welded construction is to be in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

13.2.3 Welded components are to comply with the requirements of *Vol 1, Pt 3, Ch 3 Ship Control Systems*, and be subject to stress relief heat treatment upon completion. Where an impeller has welded blades, non-destructive testing is to be carried out to an approved procedure.

13.3 Testing

13.3.1 Testing of the first installation of a new type of water jet unit is required and is to demonstrate the adequacy of the steering and reversing mechanisms during the most arduous manoeuvres.

Section 14
Thrusters

14.1 Design and construction

14.1.1 For details of design and construction requirements, *see Vol 2, Pt 4, Ch 2 Water Jet Systems*

14.2 Azimuth thrusters

14.2.1 The performance specified for the craft is to be demonstrated.

14.2.2 The actual values of steering torque are to be verified during sea trials to confirm that the design maximum dynamic duty torque has not been exceeded.

14.3 Tunnel thrusters

14.3.1 It is to be demonstrated that the thruster unit meets the specified performance.

Section 15
Steering systems

15.1 Design

15.1.1 For details of design requirements, *see Vol 2, Pt 6, Ch 1 Steering Gear*

15.2 Construction

15.2.1 The requirements of the Rules relating to the testing of Class I pressure vessels, piping and related fittings including hydraulic testing apply.

15.3 Type testing

15.3.1 Each type of power unit pump is to be subjected to a type test. The type test is to be for a duration of not less than 100 hours, the test arrangements are to be such that the pump may run in idling conditions, and at maximum delivery capacity at maximum working pressure. During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another should occur at least as quickly as on board. During the whole test no abnormal heating, excessive vibration or other irregularities are permitted. After the test, the pump is to be opened out and inspected. Type tests may be waived for a power unit which has been proven to be reliable in marine service.

15.4 Testing

15.4.1 After installation on board, the steering unit is to be subjected to the applicable hydrostatic and running tests.

15.4.2 The steering system is to be demonstrated to show that the requirements of the Rules have been met. The trial is to include the operation of the following:

(a) The steering system, including demonstration of the functional performances.
(b) The steering power units, including transfer between steering power units.
(c) The isolation of one power actuating system, checking the time for regaining steering capability.
(d) The hydraulic fluid recharging system (may be effected at the dockside).
(e) The alternative power supply and emergency hand pump operation.
(f) The steering controls, including transfer of control and local control.
(g) The means of communication between the steering compartment and the wheelhouse; also, the engine room, if applicable (may be effected at the dockside).
(h) The alarms and indicators (may be effected at the dockside).
(i) Where the steering system is designed to avoid hydraulic locking, this feature is to be demonstrated (may be effected at the dockside).

■ *Section 16* Sea trials

16.1 Sea trials requirements

16.1.1 Sea trials are to be of sufficient duration and carried out under normal operating conditions applicable to the intended class notation. Individual Chapters give specific requirements.

16.2 Programme

16.2.1 Sea trials are to include the demonstration of:

(a) The adequacy of the starting arrangements of the main engines, auxiliary systems and emergency generators.
(b) The effectiveness of the steering gear control systems, *see Vol 2, Pt 1, Ch 3, 15.4 Testing 15.4.2*.
(c) Manoeuvring, to include:

- starting;
- normal and emergency stopping;
- reversing;
- governor testing;
- safety devices and associated indicators; and
- alarms.

(d) The redundancy arrangements.

(e) Tooth contact markings in geared installations using a recognised technique. The marking is to be as detailed in *Vol 2, Pt 1, Ch 3, 10.6 Meshing tests*
(f) For controllable pitch propellers, the pitch setting under failure conditions.
(g) Operation of sliding watertight doors under working conditions.
(h) Anchoring test to demonstrate that the windlass with brakes, etc. functions satisfactorily, and that the power to raise the anchor can be developed and satisfies the Rule requirements. *See Vol 1, Pt 3, Ch 5, 7 Towing arrangements*.
(i) Operation of bilge and dewatering systems to dry compartments.

16.3 Performance testing

16.3.1 The performance of main propulsion machinery is to be demonstrated at full power in accordance with an agreed trials schedule. Engine changeover arrangements are to be demonstrated where applicable.

16.3.2 It is to be verified that the propeller performs satisfactorily under ahead and astern conditions. Where controllable pitch propellers are fitted, the free route astern trial is to be carried out with the propeller blades set in the full pitch astern condition.

16.3.3 It is to be verified that large movements of resiliently mounted machinery do not occur during start up and stop, or during normal operating conditions.

16.3.4 The installation should be tested to ensure that gas turbines cannot be continuously operated within any speed range where excessive vibration, stalling or surging may be encountered.

16.3.5 Overloading of machinery is not to occur under continuous astern power.

16.3.6 The following information is to be available on board for the use of designated personnel:

- The results of trials to determine stopping times, ship headings and distance;
- For ships having multiple propellers, the results of trials to determine the ability to navigate and manoeuvre with one or more propellers inoperative;
- For ships having a single propulsor driven by multiple engines or electric motors, the results of trials to determine the ability to navigate and manoeuvre with the largest engine or electric motor inoperative.

16.3.7 It is to be demonstrated at the sea trial that the stopping distance achieved when the ship is initially proceeding ahead with a speed of at least 90 per cent of the ship's speed corresponding to 85 per cent of the maximum rated propulsion power should not exceed 15 ship lengths after the astern order has been given. However, if the displacement of the ship makes this criterion impracticable then in no case should the stopping distance exceed 20 ship lengths.

■ *Section 17* Risk Assessment (RA)

17.1 General

17.1.1 A Risk Assessment (RA) supported using a technique selected from IEC/ ISO 31010 *Risk Management – Risk Assessment techniques* is to be performed. The technique selected is to be carried out in accordance with the relevant International Standard or applicable National Standard and with *Vol 2, Pt 1, Ch 3, 17.1 General 17.1.2* for systems (a), (b) and (c) as specified in *Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.7*. A justification is to be provided which demonstrates the suitability of the Standard and analysis technique chosen.

17.1.2 The RA is to demonstrate that suitable risk mitigation has been achieved for all normal and reasonably foreseeable abnormal conditions. The scope of analysis required for each system is defined in *Vol 2, Pt 1, Ch 3, 17.1 General 17.1.3* and in the respective parts of the Rules.

Note A reasonably foreseeable abnormal condition is an event, incident or failure that:

- has happened and could happen again;
- has not happened but is considered possible. Where the likelihood is considered extremely unlikely or the consequences are trivial, and no further prevention or mitigation action is to be taken, then this is to be justified;
- is planned for (e.g. emergency actions cover such a situation, maintenance is undertaken to prevent it, etc.).

Note These conditions should be identified by:

- using analysis processes that are capable of revealing abnormal conditions;
- employing a mix of personnel including: designers, operators, persons who carry out maintenance, those with relevant domain knowledge and understanding, and competent safety/risk professionals to apply the processes;
- referencing relevant events and historic data; and
- documenting the results of the analysis.

17.1.3 The RA is to be organised in terms of items of equipment and function. The effects of item failures or damage at stated level and at higher levels are to be analysed to determine the effects on the system as a whole. Actions for mitigation are to be determined.

17.1.4 The RA is to:

(a) Identify the equipment or sub-system and their modes of operation and the equipment;
(b) Identify potential failure modes and damage situations and their causes;
(c) Evaluate the effects on the system of each failure mode and damage situation;
(d) Identify measures for reducing the risks associated with each failure mode;
(e) Identify measures for failure mitigation; and
(f) Identify trials and testing necessary to prove conclusions.

17.1.5 At sub-system level it is acceptable, for the purpose of these Rules, to consider failure of equipment items and their functions, e.g. failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed. In addition, failure need only be dealt with as a cause of failure of the pump.

17.1.6 Where RA is used for consideration of systems that depend on software based functions for control or co-ordination, the analysis is to investigate failure of the function rather than a specific analysis of the software code.

■ *Section 18* Fin stabilisers

18.1 Design and construction

18.1.1 For requirements relating to fin stabiliser scantlings, arrangements, foundations, supporting structure and watertight integrity, *see Vol 1, Pt 3, Ch 3, 1 General*.

18.1.2 Fin stabiliser actuating systems are to be consistent with the requirements of *Vol 2, Pt 6, Ch 1, 5 Design and construction* as applicable.

18.1.3 Materials for components of fin stabilisers are to be consistent with the requirements of *Vol 2, Pt 6, Ch 1, 3 Materials* as applicable.

18.1.4 Control and electrical engineering systems are to comply with the requirements of *Vol 2, Pt 9 Electrotechnical Systems*and *Vol 2, Pt 10 Human Factors* respectively as applicable.

18.2 Performance and control

18.2.1 Fin stabilisers are to be capable of satisfying the specified functional performance requirements as detailed in the System Design Description, *see Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.13*.

18.2.2 For retractable type fin stabilisers, the servo system arrangements are to be capable of extending the fins fully at the ship's maximum service speed and in the most onerous environmental conditions, for which the ship is designed, *see Vol 1, Pt 5, Ch 2, 2.3 Wave environment*.

18.2.3 After setting to work, the fin stabiliser system is to be entirely automatic irrespective of ship speed or sea state.

18.2.4 Where provision is made for an automatic forced roll facility, the roll amplitude and period are to be manually adjustable. Forced induction of rolling motion is not to result in an unsafe condition for the ship, equipment or the crew. The arrangements are also to satisfy the following:

(a) An automatic forced roll facility is to be selectable by a switch located on the navigating bridge which is located or protected so as to prevent inadvertent operation of this function.
(b) Controls are to be provided on the navigating bridge to manually adjust the amplitude and periodicity of the induced rolling.

18.2.5 Failure of any part of the fin stabiliser unit or its control system is not to result in an unsafe condition which will have detrimental effect on the ship's operating or sea-keeping capability.

18.2.6 In the event of failure of the fin actuating system, a hand pump is to be provided, mounted in a readily accessible position, which is capable of moving the fin to a known position and securing it in that position in the absence of electrical power, and being operated by no more than two men when the ship is stopped.

18.2.7 Consideration is to be given to hydraulic locking or any other condition where the equipment becomes mechanically locked and cannot be operated. Where the possibility of hydraulic locking cannot be avoided, a clear indication of hydraulic lock is to be provided at the stabiliser control position.

18.3 Control, monitoring and alarms

18.3.1 Fin stabiliser actuating control arrangements are to be located in readily accessible positions that have means of communication provided to the machinery control station and the navigating bridge.

18.3.2 Fin stabiliser function indicators are to be provided on the navigating bridge and at the main machinery control station.

18.3.3 The fin position feedback signals are to be independent of the actuating systems.

18.3.4 Alarms and monitoring requirements are indicated in *Table 3.18.1 Alarms and monitoring*.

18.3.5 All alarms associated with fin stabiliser faults are to be indicated on the navigating bridge and in accordance with the requirements of *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*.

Table 3.18.1 Alarms and monitoring

Item	Alarm	Note
Stabiliser system active	—	Indication, *see Vol 2, Pt 1, Ch 3, 18.3 Control, monitoring and alarms*
Deviation of actual fin angle position from that demanded	Fault	*See Vol 2, Pt 1, Ch 3, 18.3 Control, monitoring and alarms 18.3.3*
Fin angle limit exceeded	Fault	
Roll angle	High	
Position indicator of fin	—	Indication, *see Vol 1, Pt 3, Ch 3, 3.1 General 3.1.16*
Fin stabiliser power units, power	Failure	
Control system power	Failure	
Fin stabiliser hydraulic oil tank level	Low	Each tank to be monitored
Hydraulic oil temperature	High	Where oil cooler is fitted
Hydraulic lock	Fault	Where more than one system (either power or control) can be operated simultaneously each system is to be monitored (*see* Note)
Hydraulic oil filter differential pressure	High	When oil filters are fitted
Note This alarm is to identify the system at fault and to be activated when (for example): Position of the variable displacement pump control system does not correspond with given order; or incorrect position of 3-way full flow valve or similar in constant delivery pump system is detected.		

18.4 Trials and testing

18.4.1 After installation on board the fin stabiliser unit is to be subject to hydrostatic and running tests.

18.4.2 Testing and trials are to be carried out in accordance with procedures that have been agreed between the Shipyard, Owner/Operator and LR. The testing is to demonstrate:

(a) The stabiliser system including the functional performances specified in the System Design Description required by *Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.13*.
(b) Extending and retracting the fins.
(c) Alternative electrical power supply arrangements where provided and functional capability of the emergency hand pump arrangements.
(d) Stabiliser controls.
(e) The alarms and indicators.
(f) Where the stabiliser system is designed to avoid hydraulic locking, this feature is to be demonstrated.

■ *Section 19*
Fired galley arrangements

19.1 Oil and liquefied petroleum gas fired galleys

19.1.1 The use of oil or liquefied petroleum gas fired galleys is acceptable provided arrangements are also acceptable to the Naval Administration and the requirements of *Vol 2, Pt 1, Ch 3, 19.1 Oil and liquefied petroleum gas fired galleys 19.1.2* are complied with.

19.1.2 The fuel oil tank is to be located outside the galley and is to be fitted with approved means of filling and venting.

19.1.3 The fuel supply to the burners is to be controlled from a position which will always be accessible in the event of a fire occurring in the galley.

19.1.4 The galley is to be well ventilated.

19.1.5 When liquefied petroleum gas is used, bottles are to be stored on the open deck or in a well ventilated space which only opens to the open deck. Protection against military action is to be provided.

19.1.6 The piping design is to be in accordance with the requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements* as applicable.

■ *Section 1* General

1.1 Scope

1.1.1 The requirements of this Chapter apply to the welding of pressure vessels and process equipment, heating and steam raising boilers and pressure pipes. The allocation of Class is determined from the design criteria referenced in *Vol 2, Pt 7, Ch 1 Piping Design Requirements* and *Vol 2, Pt 8 Pressure Plant*.

1.1.2 Fusion welded pressure vessels will be accepted only if manufactured by firms equipped and competent to undertake the quality of welding required for the Class of vessel proposed. For Class 1, 2/1 and 2/2 pressure vessels, the manufacturer's works are to be approved in accordance with the requirements specified in *Materials and Qualification Procedures for Ships*, Book A Procedure MQPS 0-4.

1.1.3 For pressure vessels which only have circumferential seams, *see Vol 2, Pt 8, Ch 1, 1.5 Classification of fusion welded pressure vessels 1.5.4* and *Vol 2, Pt 8, Ch 2, 1.5 Classification of fusion welded pressure vessels 1.5.5*.

1.2 General requirements for welding plant and welding quality

1.2.1 In the first instance, and before work is commenced, the Surveyors are to be satisfied that the required quality of welding is attainable with the proposed welding plant, equipment and procedures in accordance with the guidelines specified in *Materials and Qualification Procedures for Ships Book A, Procedure 0-4*.

1.2.2 All welding is to be in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

■ *Section 2* Manufacture and workmanship of fusion welded pressure vessels

2.1 General requirements

2.1.1 Prior to commencing construction, the design of the vessel is to be approved where required by *Vol 2, Pt 8, Ch 1, 1.6 Plans* and *Vol 2, Pt 8, Ch 2, 1.6 Plans*.

2.1.2 Pressure vessels will be accepted only if manufactured by firms that have been assessed and approved in accordance with MQPS 0-4.

2.2 Materials of construction

2.2.1 Where the construction requires post-weld heat treatment, consideration should be given to certifying the material after subjecting the test pieces to a simulated heat treatment.

2.2.2 Pressure vessels are to be constructed and examined in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the Rules for Materials, unless more stringent requirements are specified.

2.3 Tolerances for cylindrical shells

2.3.1 Measurements are to be made to the surface of the parent plate and not to a weld, fitting or other raised part.

2.3.2 In assessing the out-of-roundness of pressure vessels, the difference between the maximum and minimum internal diameters measured at one cross-section is not to exceed the amount given in *Table 4.2.1 Tolerances for cylindrical shells*.

Table 4.2.1 Tolerances for cylindrical shells

Nominal internal diameter of vessel, in mm	Difference between maximum and minimum diameters	Maximum departure from designed form
≤ 300	1,0 per cent of internal diameter	1,2 mm
> 300 ≤ 460		1,6 mm
> 460 ≤ 600		2,4 mm
> 600 ≤ 900		3,2 mm
> 900 ≤ 1220		4,0 mm
> 1220 ≤ 1520		4,8 mm
> 1520 ≤ 1900		5,6 mm
> 1900 ≤ 2300	19 mm	6,4 mm
> 2300 ≤ 2670		7,2 mm
> 2670 ≤ 3950		8,0 mm
> 3950 ≤ 4650	19 mm	0,2 per cent of internal diameter
> 4650	0,4 per cent of internal diameter	

2.3.3 The profile measured on the inside or outside of the shell, by means of a gauge of the designed form of the shell, and having a chord length equal to one-quarter of the internal diameter of the vessel, is not to depart from the designed form by more than the amount given in *Table 4.2.1 Tolerances for cylindrical shells*. This amount corresponds to *x* in *Figure 4.2.1 Tolerances for cylindrical shells*.

2.3.4 Shell sections are to be measured for out-of-roundness, either when laid flat on their sides or when set up on end. When the shell sections are checked while lying on their sides, each measurement for diameter is to be repeated after turning the shell through 90° about its longitudinal axis. The two measurements for each diameter are to be averaged, and the amount of out-of-roundness calculated from the average values so determined.

2.3.5 Where there is any local departure from circularity due to the presence of flats or peaks at welded seams, the departure from designed form shall not exceed that of *Table 4.2.1 Tolerances for cylindrical shells*.

2.3.6 The external circumference of the completed shell is not to depart from the calculated circumference (based upon nominal inside diameter and the actual plate thickness) by more than the amounts given in *Table 4.2.2 Circumferential tolerances*.

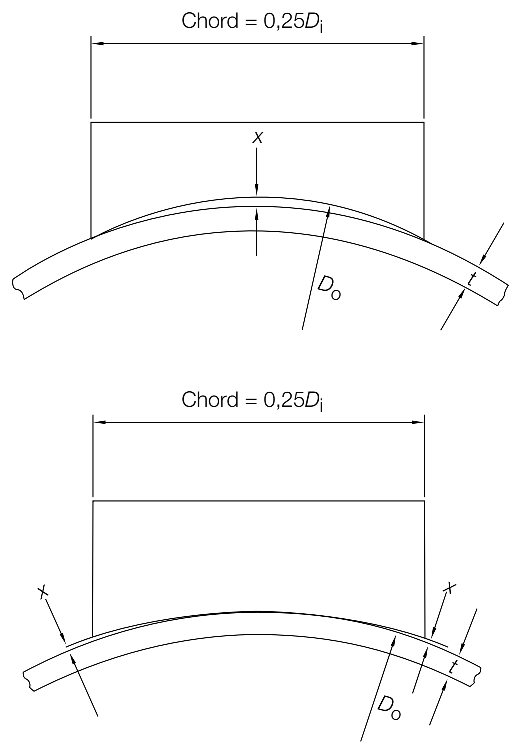


Figure 4.2.1 Tolerances for cylindrical shells

Table 4.2.2 Circumferential tolerances

Outside diameter (nominal inside diameter plus twice actual plate thickness), in mm	Circumferential tolerance
300 to 600 inclusive	±5 mm
Greater than 600	±0,25 per cent

■ *Section 3*
Repairs to welds on fusion welded pressure vessels

3.1 General

3.1.1 Repairs to welds on fusion welded pressure vessels are to be in accordance with the requirements of, *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

Section 4
Post-weld heat treatment of pressure vessels

4.1 General

4.1.1 Post-weld heat treatment of fusion welded pressure vessels is to be in accordance with the requirements of, *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

Section 5
Welded pressure pipes

5.1 General

5.1.1 Fabrication of pipework is to be carried out in accordance with the requirements of *Ch 13, 5 Specific requirements for pressure pipework* of the Rules for Materials.

5.2 Welding workmanship

5.2.1 Preheating is to be effected by a method which ensures uniformity of temperature at the joint. The method of heating and the means adopted for temperature control are to be to the satisfaction of the Surveyors.

5.2.2 All welding is to be performed in accordance with the approved welding procedures by welders who are qualified for the materials, joint types and welding processes employed.

5.2.3 Welding without filler metal is generally not permitted for welding of duplex stainless steel materials.

5.2.4 All welds in high pressure and high temperature pipelines are to have a smooth surface finish and even contour; if necessary, they are to be made smooth by grinding.

5.2.5 Check tests of the quality of the welding are to be carried out periodically at the discretion of the Surveyors.

Section 6
Non-Destructive Examination

6.1 General

6.1.1 Non-Destructive Examination (NDE) of pressure vessels is to be performed in accordance with the requirements of *Ch 13, 5 Specific requirements for pressure pipework* of the Rules for Materials.

Section 1
General

1.1 Application

1.1.1 Adequate spare parts for the propelling and auxiliary machinery for Mobility systems and Ship Type systems, together with the necessary tools for maintenance and repair shall be readily available for use.

1.1.2 The spare parts to be supplied and their location is to be the responsibility of the Owner but must take into account the design and arrangements of the machinery and the intended service and operation of the ship. Account should also be taken of the recommendations of the manufacturers.

1.2 Guidance for spare parts

1.2.1 For general guidance purposes, spare parts for main and auxiliary machinery installations are shown in the LR's *Spare Gear Guidance* located on Class Direct.

Reciprocating Internal Combustion Engines

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the requirements for Machinery and Engineering Systems in *Vol 2, Pt 1, Ch 1 General Requirements for Classification of Engineering Systems* and *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*.

1.1.2 The requirements of this Chapter are applicable to reciprocating internal combustion engines operating on liquid, gas or dual fuel for use in Mobility or Ship Type systems (hereinafter referred to as engines). The requirements of *Vol 2, Pt 2, Ch 1, 4 Crankshaft design* do not apply to engines intended for Mobility or Ship Type systems where power does not exceed 110 kW.

1.1.3 Primary exhaust gas emissions abatement plant (where fitted) is to meet the requirements of this Chapter; additionally, it is to meet the requirements of *Vol 2, Pt 12 Emissions Abatement Plant*. Where secondary exhaust gas emissions abatement systems are fitted to engines, they are to meet the requirements of*Vol 2, Pt 12 Emissions Abatement Plant*.

1.1.4 For the purposes of this Chapter engine type, expressed by the manufacturer/licensor’s designation, is defined by:

(a) the bore and stroke;
(b) the method of injection (i.e. direct injection, indirect injection, pilot injection);
(c) the fuel pump and injection system (independent line to fuel oil valve, common rail);
(d) the valve and injection operation (by cams or electronically controlled);
(e) the fuel(s) used (liquid, dual-fuel, gaseous, etc.);
(f) the working cycle (4-stroke, 2-stroke);
(g) the gas exchange (naturally aspirated, turbocharged, etc.);
(h) the method of turbocharging (pulsating system, constant pressure system);
(i) the charging air cooling system (with or without intercooler, number of stages);
(j) cylinder arrangement (in-line, vee, etc.);

(k) the maximum continuous power per cylinder (or maximum continuous brake mean effective pressure) at maximum continuous speed;
(l) the manufacturer and type of governor (and control system if applicable) fitted.

1.1.5 A complete engine includes the control system, turbocharger(s) and all ancillary systems and equipment referred to in this Chapter that are used for operation of the engine for which there are rule requirements; this includes systems allowing the use of different fuel types.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in *Vol 2, Pt 1, Ch 3, 4.3 Power ratings*.

1.3 Power conditions for generator sets

1.3.1 Auxiliary engines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output (kW) and of developing for a short period (15 minutes) an overload power of not less than 10 per cent (*see Vol 2, Pt 9 Electrotechnical Systems*).

1.4 Inclination of ship

1.4.1 Main and auxiliary engines for Mobility systems or Ship Type systems are to operate satisfactorily under the conditions as shown in *Table 3.4.2 Inclinations*.

1.5 Turning gear

1.5.1 Turning gear is to be provided for all engines to facilitate operating and maintenance regimes as required by the manufacturer. Manuals are to be provided and are to comply with the requirements of *Vol 2, Pt 1, Ch 1, 4.6 Through life operation principles 4.6.7*.

1.5.2 The turning gear for all propulsion engines is to be power-driven and is to be continuously rated at a value to ensure protection to the weakest part of the machinery.

1.5.3 The turning gear for auxiliary engines may be hand operated (manual) except where this is not practicable, in which case the provision of *Vol 2, Pt 2, Ch 1, 1.5 Turning gear 1.5.2* is to be complied with.

1.5.4 The turning gear for all engines is to be fitted with safety Interlocks which prevent engine operation when engaged *see Vol 2, Pt 1, Ch 3, 4.13 Electromagnetic compatibility (EMC)*. Indication of engaged/disengaged is to be provided at all start positions. In the case of unattached hand operated turning gear engine operation may be prevented by manual means including the provision of warning devices or notices.

1.5.5 The remote control device of power-driven turning gear is to be so designed that power is removed from the turning gear when the operating switch is released.

1.5.6 Means are to be provided to secure the turning gear when disengaged.

1.5.7 Overload protection arrangements are to be provided to prevent damage to the electric motor and the turning gear train.

■ *Section 2* Documents required for design review

2.1 Approval process

2.1.1 Approval of an engine type will be granted following:

(a) satisfactory design appraisal. Plans are to be submitted as required in *Table 1.2.1 Plans and particulars to be submitted*.
(b) satisfactory type testing (*see Vol 2, Pt 2, Ch 1, 12.1 Engines*).

Note Approval of the engine type is not to be confused with LR Type Approval; LR Type Approval is explained in *Vol 1, Pt 1, Ch 2, 5.1 LR Type Approval* and *Vol 2, Pt 1, Ch 1, 9 Type approval system (for information)*.

2.1.2 Each complete engine, as defined in *Vol 2, Pt 2, Ch 1, 1.1 Application 1.1.5*, intended for installation on an LR Classed vessel, is to have an LR Engine Certificate.

2.1.3 For the first engine of a type the approval process and the engine certification process may be performed simultaneously.

2.1.4 To apply for an LR Engine Certificate, the following are to be submitted:

(a) a list of all documents identified in the ‘for information’ and ‘for appraisal’ columns of Table 1.2.1 Plans and particulars to be submitted with the relevant drawing numbers and revision status. This list is to cross-reference the approved plans previously submitted in accordance with *Vol 2, Pt 2, Ch 1, 2.1 Approval process 2.1.1* and identify any plans that have been modified.

(b) where there is a licensor/licensee arrangement the list required by *Vol 2, Pt 2, Ch 1, 2.1 Approval process 2.1.4* is to cross-reference the drawings submitted by the designer in accordance with *Vol 2, Pt 2, Ch 1, 1.1 Application 1.1.5*. This list is to identify all changes where the approved design has been modified by the licensee. Where the licensee proposes design modifications to components, a statement is to be made confirming the licensor’s acceptance of the proposed changes. If designer/licensor’s acceptance is not confirmed, the engine is to be regarded as a different type and is subject to the complete appraisal and type testing process.

(c) all documents with changes from the approved design are to be submitted for review/appraisal. In all cases the complete set of endorsed documents and the list referenced in *Vol 2, Pt 2, Ch 1, 2.1 Approval process 2.1.4*, which are to be provided by the manufacturer, will be required by the Surveyor(s) attending the manufacturer’s works. Where a licensee/licensor arrangement is in place, this set of documents may be a combination of licensor and licensee documents.

2.1.5 An LR Engine Certificate is issued upon satisfactory completion of engine assembly, with associated component testing (*see Vol 2, Pt 2, Ch 1, 3 Materials and components*) and factory acceptance testing (*see Vol 2, Pt 2, Ch 1, 10 Factory Acceptance Test and Shipboard Trials of Internal Combustion Engines*). An alternative method of engine certification is available to manufacturers approved under the Quality Assurance Scheme for Machinery (QAM). *See Vol 2, Pt 1, Ch 1, 8 Quality assurance scheme for machinery*.

2.1.6 For appraisal of emergency generator sets and turbochargers additional submissions are required. *See Vol 2, Pt 2, Ch 1, 2.2 Submission requirements 2.2.3* and *Vol 2, Pt 2, Ch 1, 2.2 Submission requirements 2.2.4*, as applicable.

2.1.7 Where required materials and components are to be manufactured, tested and certified at a manufacturer approved by LR in accordance with the Rules for the Manufacture, Testing and Certification of Materials (hereinafter referred to as Rules for Materials), *see Vol 2, Pt 2, Ch 1, 3 Materials and components*.

2.2 Submission requirements

Table 1.2.1 Plans and particulars to be submitted

Document	For information	For appraisal
	(X indicates reason for submission)	
Engine particulars (LR Form 2073 with general engine and ancillaries information, Project Guide, Marine Installation Manual) (*See* Note 1)	X	
Material specifications of principal components with information on non-destructive material tests and pressure tests		X
Engine cross-section	X	
Engine longitudinal section	X	
Engine frames, welding drawings (*See* Notes 2 and 3)		X
Main engine foundation and holding down and securing arrangements	X (metal chocks)	X (non-metallic chocks)
Bedplate and crankcase of cast design	X	
Bedplate and crankcase of welded design, with welding details and welding instructions (*See* Notes 2 and 3)		X
Bedplate/oil sump welding drawings (*See Note* 2)		X
Thrust bearing assembly (*See* Note 4)	X	
Thrust shaft or intermediate shaft (if integral with engine)		X

Thrust bearing bedplate of welded design, with welding details and welding instructions (*See* Note 2)		X
Frame (*See* Note 3), framebox (*See* Note 3) and gearcase of cast construction	X	
Tie rod	X	
Connecting rod, assembly (*See* Note 5)	X	
Crosshead, assembly (*See* Note 5)	X	
Piston rod, assembly (*See* Note 5)	X	
Piston, assembly (*See* Note 5)	X	
Piston head	X	
Cylinder jacket/ block of cast construction (*See* Note 3)	X	
Cylinder cover, assembly (*See* Note 5)	X	
Cylinder liner	X	
Counterweights (if not integral with crankshaft), including fastening	X	
Crankshaft, details (for each crankthrow)		X
Crankshaft, assembly (for each crankthrow)		X
Crankshaft calculations (*See Vol 2, Pt 2, Ch 1, 4 Crankshaft design*)	X	
Camshaft drive, assembly (*See* Note 5)	X	
Flywheel or turning-wheel	X	
Shaft coupling interface arrangement including dimensions and material details		X
Details of shielding and insulation of exhaust pipes and other parts operating at an elevated temperature, which might be impinged by flammable fluid(s) as a result of a system failure	X	
Schematic layout or other equivalent documents for the engine: (*See* Note 6)		
• Starting and control air systems		X
• Fuel system		X
• Lubricating oil system		X
• Cooling water system		X
• Hydraulic systems		X
• Engine control and safety system		X
High pressure fuel injection pump assembly	X	
High pressure parts for fuel oil injection system (*See* Note 7)		X
Shielding arrangements for high pressure piping - fuel, hydraulic and flammable oils (*See Vol 2, Pt 2, Ch 1, 8.1 Oil fuel, hydraulic and high-pressure oil systems 8.1.1*)		X
Fastening arrangements for main bearings	X	
Fastening arrangements for cylinder heads and exhaust valve (two stroke design)	X	
Fastening arrangements for connecting rods	X	
Vibration dampers/detuners and moment compensators	X	
Construction and arrangement of vibration dampers	X	
Details of mechanical joints of piping systems		X
Oil mist detection and/or alternative arrangements		X
Construction of accumulators (common rail) for electronically controlled engine		X
Construction of common accumulators (common rail) for electronically controlled engine		X
Construction of accumulators for hydraulic oil and fuel oil		X

Arrangement and details of the crankcase explosion relief valve where applicable (*See Vol 2, Pt 2, Ch 1, 10 Factory Acceptance Test and Shipboard Trials of Internal Combustion Engines*)		X
Calculation results for crankcase explosion relief valves (*See Vol 2, Pt 2, Ch 1, 10 Factory Acceptance Test and Shipboard Trials of Internal Combustion Engines*)		X
Construction and arrangements of hydraulic systems for actuation of sub-systems:		
• Control valves, high-pressure pumps, pipes and accumulators	X	
• Drive for high pressure pumps	X	
• Valve bodies, if applicable	X	
For engine control, alarm monitoring and safety systems, the plans and information *Vol 2, Pt 2, Ch 1, 2.2 Submission requirements 2.2.2* (*See* Note 8)		X
Generator set test results that state the engine maximum load steps which satisfy the quality of power supply requirements specified in *Vol 2, Pt 9, Ch 1, 2.1 Quality of power supplies (QPS)*)		X
Planned operating profiles for the vessel at sea and during manoeuvring as agreed with the Operators		X
List of sub-contractors for main parts	X	
Operation and service manuals (*See* Note 9)	X	
Risk-based analysis (for engine control system) (*See* Note 10)	X	
Test program resulting from risk-based analysis (for engine control system) (*See* Note 10)	X	
Production specifications for castings and welding procedures	X	
Evidence of quality control system for engine design, production and in-service maintenance (*See* Notes 5 and 11)	X	
Type approval certification for environmental tests of control components (*See* Note 12)	X	
Details of the engine type test program and the type test report (*See* Note 13)		X
Fatigue analysis for all high pressure oil fuel and hydraulic oil piping arrangements (*See* Note 14)		X
Engine test schedule (FAT and shipboard trials, *see Vol 2, Pt 2, Ch 1, 2.2 Submission requirements 2.2.1*)		X
Documentation verifying compliance with inclination limits (*See Vol 2, Pt 1, Ch 3, 4.6 Inclination of ship*)		X
Combustion pressure-displacement relationship		X
Plans and details for dead ship condition starting arrangements, *see Vol 2, Pt 7, Ch 3, 12.11 Dead ship condition starting arrangements*.		X

Note 1. LR Form 2073 will be supplied on application. Note that the turbochargers, if required to be type approved, are to have plans and particulars submitted as detailed in *Vol 2, Pt 2, Ch 1, 2.2 Submission requirements 2.2.4*.

Note 2. For approval of materials and weld procedure specifications. The weld procedure specification is to include details of pre- and post-weld heat treatment, weld consumables and fit-up conditions.

Note 3. For each cylinder for which dimensions and details differ.

Note 4. If integral with engine and not integrated in the bedplate.

Note 5. Including identification of components to ensure traceability in accordance with the Rules for Materials.

Note 6. Details of the system so far as supplied by the engine manufacturer such as: main dimensions, operating media and maximum working pressures.

Note 7. The documentation to contain specifications for pressures, pipe dimensions and materials.

Note 8. The System Design Description required by *Table 1.2.2 Additional Plans and particulars to be submitted* is to include a general overview of the operating principles, supported by schematics explaining the functionality of individual systems and sub-systems. The information is to relate to the engine capability and functionality under defined operating and emergency conditions such as recovery from a failure or malfunction, with particular reference to the functioning of programmable electronic systems and any sub-systems. The information is also to indicate if the engine has different modes of operation, such as to limit exhaust gas emissions and/or to run under an economic fuel consumption mode or any other mode that is electronically controlled.

Note 9. Operational manuals are to contain maintenance requirements (servicing and repair) including details of any special tools and gauges that are to be used with their fitting/settings together with any test requirements on completion of maintenance. They are to include a description of each system's particulars and include reference to the functioning of sub-systems.

Note 10. Where engines rely on hydraulic, pneumatic or electronic control of fuel injection and/or valves, the risk-based analysis is to address the mechanical, pressure containing, electrical, electronic and programmable electronic systems and arrangements that support the operation of the engine. It is to demonstrate that failure of the control system will not result in the operation of the engine being degraded beyond acceptable performance criteria for the engine and that suitable risk mitigation has been achieved in accordance with *Vol 2, Pt 2, Ch 1, 4.2 Information to be submitted*. The risk-based analysis will not be explicitly approved by LR.

Note 11. Including quality plan for sourcing, traceability, design, installation and testing of all components used in the fuel and hydraulic oil systems installed with the engine. *See Vol 2, Pt 2, Ch 1, 8.1 Oil fuel, hydraulic and high-pressure oil systems 8.1.11*.

Note 12. Tests are to demonstrate the ability of the control, protection and safety equipment to function as intended under the specified testing conditions as per Lloyd's Register Type Approval Test Specification Number 1.

Note 13. The type test report may be submitted shortly after the conclusion of the type test. For electronically controlled engines evidence of type testing of the engine with the programmable electronic system, or a proposed factory acceptance test plan at the engine builders with the programmable electronic system functioning, is to be submitted to verify the functionality and behaviour under normal operating and fault conditions of the programmable electronic control system. Where required this is to include proposals for short-term, high power operation.

Note 14. Required for engine operation where failure of the pipe or its connection or a component would be the cause of engine unavailability. The analysis is to concentrate on high pressure components and sub-systems and recognise the pressures and fluctuating stresses that the pipe system may be subject to in normal service.

2.2.1 Schedule of testing at the engine packager's or system integrator's facility, pre-sea trial commissioning and sea trials is to be submitted. The test schedules are to identify all modes of engine operation and the sea trials are to include typical port manoeuvres under all intended engine operating modes. The schedule is to include:

(a) testing and trials to demonstrate that the engine is capable of operating as described in *Table 1.2.1 Plans and particulars to be submitted*, Note 8;
(b) tests to verify that the response of the complete mechanical, hydraulic, electrical and electronic system is as predicted for the intended operational modes; and
(c) testing required to verify the conclusions of the risk-based analysis.

The scope of these tests is to be agreed with LR based on the risk-based analysis.

2.2.2 In addition to the applicable plans and particulars required by *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.5* to *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.8*, the following information for control, alarm, monitoring and safety systems relating to the operation of an electronically controlled engine is to be submitted:

(a) Engine configuration details, *see Vol 2, Pt 2, Ch 1, 13.3 Control engineering systems 13.3.2*.
  (i) Local and remote means to carry out system configuration.
  (ii) Engine builder procedures for undertaking configuring.
  (iii) Roles and responsibilities for configuration (e.g. Engine builder, engine packager, system integrator or other nominated party) with accompanying schedule.
  (iv) Configurable settings and parameters (including those not to be modified from a default value).
  (v) Configuration for propulsion, auxiliary or emergency engine application.

  Configuration records are to be maintained and are to be made available to the Surveyor at testing and trials and on request in accordance with *Vol 2, Pt 9, Ch 1, 1.7 Alterations and additions* and *Vol 2, Pt 9, Ch 11, 1.2 Trials 1.2.3*.
(b) Software quality plans, including configuration management documents.
(c) Software safety evidence.
(d) Software assessment inspection report such as SCA or IEC 61508, as applicable.

2.2.3 For emergency engines, evidence and details showing compliance with *Vol 2, Pt 2, Ch 1, 13.5 Emergency engines*.

2.2.4 For turbochargers, the following plans and particulars are to be submitted for information:

(a) Cross-sectional drawing with principal dimensions and materials of housing components for containment evaluation.
(b) Drawings of the housing and rotating parts including details of blade fixing.
(c) Material specifications (chemical composition and mechanical properties) of all parts mentioned in (b) above including details of the material and quality control system to be used for these parts.
(d) Welding details and welding procedure of above mentioned parts, if applicable.
(e) Documentation of containment in the event of disc fracture, *see Vol 2, Pt 2, Ch 1, 11.5 Containment*.
(f) Type test reports.
(g) Operational data and limitations, i.e.:

- Maximum permissible operating speed (rpm)
- Alarm level for over-speed
- Maximum permissible exhaust gas temperature before turbine
- Alarm level for exhaust gas temperature before turbine
- Minimum lubrication oil inlet pressure
- Lubrication oil inlet pressure low alarm set point
- Maximum lubrication oil outlet temperature
- Lubrication oil outlet temperature high alarm set point
- Maximum permissible vibration levels, i.e. self- and externally generated vibration

(Alarm levels may be equal to permissible limits but are not to be reached when operating the engine at 110 per cent power or at any approved intermittent overload beyond 110 per cent.)

(h) Arrangement of lubrication system, all variants within a range.
(i) A list of main current suppliers and subcontractors for rotating parts and an operation and maintenance manual.
(j) Documentation* of safe torque transmission when the disc is connected to the shaft by an interference fit, *see Vol 2, Pt 2, Ch 1, 11.6 Disk-shaft shrinkage fit*.
(k) Information on expected lifespan, considering creep, low cycle fatigue and high cycle fatigue.
(l) Operation and maintenance manuals*.

Note * Applicable to two sizes in a generic range of turbochargers.

2.2.5 The following information is to be submitted to LR for acceptance of oil mist detection equipment and alarm arrangements:

(a) Description of oil mist detection equipment and system including alarms.
(b) Copy of the test house report in accordance with the requirements of Test Specification No. 4. *See also Vol 2, Pt 2, Ch 1, 12.4 Crankcase oil mist detection system*.
(c) Schematic layout of engine oil mist detection arrangements showing location of detectors/sensors and piping arrangements and dimensions.
(d) Maintenance and test manual which is to include the following information:
    (i) Intended use of equipment and its operation;
    (ii) Functionality tests to demonstrate that the equipment is operational and that any faults can be identified and corrective actions notified;
    (iii) Maintenance routines and spare parts recommendations;
    (iv) Limit setting and instructions for safe limit levels; and
    (v) Where necessary, details of configurations in which the equipment is and is not to be used.

2.2.6 Where considered necessary Lloyd's Register (hereinafter referred to as 'LR') may require additional documentation to be submitted.

2.3 Additional submission requirements

2.3.1 In addition to the requirements of *Vol 2, Pt 2, Ch 1, 2.2 Submission requirements* and *Table 1.2.1 Plans and particulars to be submitted*, the plans and information in *Vol 2, Pt 2, Ch 1, 2.3 Additional submission requirements 2.3.2* and *Table 1.2.2 Additional Plans and particulars to be submitted* are to be submitted.

2.3.2 Risk Assessment (RA) as required by *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems* is to be submitted. The RA is to be carried out in accordance with the requirements of *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)* and is to include the following associated sub-systems:

- Starting and stopping.
- Fuel oil.
- Lubricating oil.
- Cooling water (fresh and sea).
- Air induction.
- Exhaust.
- Engine mounting.
- Control and monitoring.
- Electrical power supplies.
- Hydraulic oil (for valve lift).

It is not necessary to consider failure modes relating to the engine components.

Table 1.2.2 Additional Plans and particulars to be submitted

Document	For information	For appraisal
	(X *indicates reason for submission)*	
Control engineering aspects in accordance with *Vol 2, Pt 9 Electrotechnical Systems*.		X
Details of the securing and collision arrangements (*see also Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.5* and *Vol 2, Pt 1, Ch 3, 5.3 Machinery fastenings* to *Vol 2, Pt 1, Ch 3, 5.6 Resin chocks*).		X
Arrangement of interior lighting, where provided.		X
Calculations and information for short-term high power operation where applicable.	X	
Power/speed operational envelope.	X	
Where it is proposed to use alloy castings, micro alloyed or alloy steel forgings or iron castings: Details of the chemical composition, heat treatment and mechanical properties.		X
System Operational Concept covering the Propulsion system, *see Vol 2, Pt 1, Ch 3, 3.4 System operational concept*.		X
System Design Description for engine systems, *see Vol 2, Pt 1, Ch 3, 3 Documentation required for design review*.		X

■ *Section 3*
Materials and components

3.1 Crankshaft materials

3.1.1 The specified minimum tensile strength of castings and forgings for crankshafts is to be selected within the following general limits:

(a) Carbon-manganese steel castings –

400 to 550 N/mm^2.

(b) Carbon-manganese steel forgings (normalised and tempered) –

400 to 600 N/mm^2.

(c) Carbon-manganese steel forgings (quenched and tempered) –

not exceeding 700 N/mm^2.

(d) Alloy steel castings –

not exceeding 700 N/mm^2.

(e) Alloy steel forgings –

not exceeding 1000 N/mm^2.

(f) Spheroidal or nodular graphite iron castings –

370 to 800 N/mm^2.

Table 1.3.1 Test and certification requirements for engine components

Part	Materials Tests				Component Tests		LR Component Certification
	Material Properties *see* Note 1	Surface Inspection *see* Note 2	Ultrasonic Inspection	LR Material Certification *see* Note 3	Hydraulic testing *see* Note 5	Visual inspection	
					(All Engines)		
Steel castings for welded bedplates	All	All	All	a	-	fit-up + post-welding	X
Steel forgings for welded bedplates	All	-	-	a	-	fit-up + post-welding	X
Plates for welded bedplates, frames and entablatures	All	-	-	a *see* Note 4	-	fit-up + post-welding	X
Bearing transverse girders	All	All	All	a	-	V	X
Crankcases, welded or cast	All	-	-	a *see* Note 4	-	V	X
Welded frame box	All	All	All	b *see* Note 4	-	fit-up + post-welding	X
Engine block	>400kW /cylinder	-	-	a	1,5p	V	X
Cylinder block	All	-	-	a	1,5p	V	X
Welded cylinder frames	All	All	All	a *see* Note 4	-	fit-up + post-welding	X
Tie rod	All	Bore>400mm *see* Note6	-	b	-		-
Bolts and studs for cylinder covers, crossheads, main bearings, tie rods and connecting rod bearings	Bore>300mm	Bore>400mm	Bore>400mm	c	-	V	-
Cylinder liner	Bore>300mm	-	-	a	7,0 bar	-	X
Cylinder cover	Bore>300mm	Bore>400mm	All *see* Note 17	a	7,0 bar *see* Note 7	V	X
Turbocharger, shaft and rotor	Bore>300mm	-	-	c	-	V	X
Turbocharger casing	*See* Note 11	*See* Note 11	*See* Note 11	c	G *see* Note 8	V	X
Crankshaft	All	All	All	a	-	V+D	X

Crankshaft coupling flange(non-integral)	Main propulsion bore>400mm	-	-	a	-	V+D	X
Semi-built crankshaft (Crankthrow, forged main journal and journals with flange)	All	All	All	a		V+D	X
Connecting rod assembly	All	All	Bore>400mm	a	-	V+D	X
Crankshaft coupling bolts	Bore>400mm	Bore>400mm	Bore>400mm	c	-	V+D	X
Crosshead	Bore>400mm	Bore>400mm	Bore>400mm	a	-	V	X
Piston rod, if applicable	Bore>400mm	Bore>400mm	Bore>400mm	a	-	V	X
Piston crown (steel)	Bore>400mm	Bore>400mm	All	a	7,0 bar *see* Note 7	V	X
Steel gear wheels for camshaft drives	Bore>400mm	Bore>400mm	-	b	-	-	-
High pressure fuel injection system - valve, pipe, pump body (pressure side) (10)	All	-	-	a	Lesser of 1,5p or p + 300 bar *see* Note 9	V	X
Coolers, both sides (12)	-	-	-	-	G	V	*See* Note 13
Accumulator of common rail fuel or servo oil system	Accumulators with a capacity>0,5 l	-	-	-	1,5p		X
Bearings for main, crosshead, and crankpin (14)	>800kW/ cylinder	-	>800kW/ cylinder	c	-	V+D	-
Piping, pumps, actuators, etc., for hydraulic systems, if applicable	All	-	All (Welds)	*See* Note 15	1,5p	V	*See* Note 13
Engine driven pumps - oil, water, fuel, bilge	-	-	-	*See* Note 15	G	-	X
Cylinder jacket cooling space (16)	-	-	-	-	G	-	-
Exhaust pipe cooling space	-	-	-	-	G	-	-
Exhaust valve cooling space	-	-	-	-	G	-	-
Air compressor inc. cylinders, liners, covers, intercoolers & after coolers (12)	Calculated crankpin≥50mm	-	-	c	Air side: 1,5p Water side: G	-	X
SYMBOLS							
Bore dimensions refer to engine cylinder bores p = Max. working pressure of item concerned		G= Pressure test at greater of 4,0 bar or 1,5p V= Visual examination of accessible surfaces by Surveyor (11)			D =Dimensional inspection, including surface condition X= LR Component Certification required		

Note 1. Material properties include chemical composition and mechanical properties, and also surface treatment such as surface hardening (hardness, depth and extent), peening and rolling (extent and applied force). All required material tests are to be carried out in accordance with the relevant Chapters of the Rules for Materials.

Note 2. Magnetic particle testing is to be carried out on ferromagnetic materials, liquid penetrant testing is only to be carried out on non-ferritic materials. Visual examination alone is not considered sufficient.

Note 3. The certificate type required refers to the Rules for Materials, *Ch 1, 3.1 General 3.1.3*.

Note 4. Where welding is carried out, welding procedures and welder qualifications are to be carried out in accordance with the Rules for Materials, *Ch 12 Welding Qualifications*.

Note 5. Hydraulic testing is applied on the water/oil side of the component. The full lengths of cooling spaces are to be tested where applicable. Tests are to be witnessed by the Surveyor and an LR Test Certificate will be issued.

Note 6. Magnetic particle testing of tie rods may be confined to the threaded portions and the adjacent material over a length equal to that of the thread.

Note 7. For forged steel cylinder covers and piston crowns alternative testing methods may be specially considered. Where the piston rod seals the piston crown cooling space, it is to be tested after assembly.

Note 8. Hydraulic testing of the cooling space. Turbocharger air coolers need only be tested on the water side.

Note 9. Where components are subjected to an autofrettage process approved by LR, the component pressure test may be omitted. The assembled system containing such components is to be shown, where practicable, to be pressure-tight as required for hydraulic systems.

Note 10. Pumps used in jerk or times pump systems need only have the assembled high pressure containing components hydraulically tested.

Note 11. Dependent upon specific application.

Note 12. Material and component certification for accumulators or coolers which are classed as pressure vessels are dependent on the operating pressure and temperature, *see Vol 2, Pt 8, Ch 2, 1.5 Classification of fusion welded pressure vessels* and *Vol 2, Pt 8, Ch 2, 1.7 Materials*.

Note 13. LR component certification required where the component is necessary for the operation of main propulsion or auxiliary engines which are the source of power for services essential for safety or for the operation of the ship at sea.

Note 14. Ultrasonic testing required to prove full contact between basic material and bearing metal; only chemical properties required for materials testing.

Note 15. Material certification requirements for pumps and piping components are dependent on the operating pressure and temperature, *see Vol 2, Pt 7, Ch 1, 2.3 Classes of piping system and components* and *Vol 2, Pt 7, Ch 1, 4 Materials*.

Note 16. Where it is more practical to test the assembled engine (i.e. for engines with a multiple cylinder engine block), a leak test at working pressure may be accepted.

Note 17. Cylinder covers and liners manufactured from spheroidal or nodular graphite iron castings may not be suitable for ultrasonic NDE, depending upon the grain size and geometry. An alternative NDE procedure is to be agreed with LR.

3.2 Materials test and inspections

3.2.1 Materials and components for engines are to be manufactured, tested and certified as indicated in *Table 1.3.1 Test and certification requirements for engine components* and in accordance with the relevant requirements of the Rule for Materials.

3.2.2 For components of novel design special consideration will be given to the acceptability of material properties and non-destructive testing requirements. For components and materials not specified in *Table 1.2.1 Plans and particulars to be submitted*, consideration will be given by LR upon submission and review of their full details.

3.2.3 With reference to *Table 1.3.1 Test and certification requirements for engine components*, certification is to be in accordance with Rules for Materials, *Ch 1, 3.1 General* and with the type as specified in *Table 1.3.1 Test and certification requirements for engine components*.

3.2.4 The certificate is to be in accordance with the Rules for Materials, *Ch 1, 3.1 General 3.1.3* where the manufacturer or material supplier operates an approved LR Quality Scheme.

3.2.5 The manufacturer is not exempted from responsibility for any relevant tests and inspections of those parts for which documentation is not explicitly requested by LR.

3.3 Hydraulic tests

3.3.1 In general, items are to be tested by hydraulic pressure as indicated in Table 1.3.1 Test and certification requirements for engine components. Where design features are such that modifications to the test requirements shown in Table 1.3.1 Test and certification requirements for engine components are necessary, alternative proposals for hydraulic tests are to be submitted for special consideration.

3.3.2 Where a manufacturer has demonstrated to LR that they have an acceptable quality management system, a manufacturer's hydraulic test certificate may be accepted for engine driven pumps as detailed in Table 1.3.1 Test and certification requirements for engine components. Recognition and acceptance of the works quality control processes can be by one of the following routes:

(a) Approval under the LR Quality Assurance Scheme for Machinery (QAM).
(b) Approval of an alternative quality scheme recognized by LR.
(c) Approval by LR through auditing of the manufacturer's quality system.

3.4 Alignment gauges

3.4.1 All main and auxiliary oil engines exceeding 220 kW are to be provided with an alignment gauge which may be either a bridge weardown gauge, or a micro-meter clock gauge for use between the crankwebs. Only one micrometer clock gauge need be supplied for each ship provided the gauge is suitable for use on all engines.

3.5 Autofrettage

3.5.1 Manufacturers who carry out autofrettage to enhance the fatigue life of components are to be approved by LR.

3.5.2 LR certificates are to be issued for components subject to autofrettage, provided the attending Surveyors are satisfied that the required process parameters and associated QA processes have been applied.

■ *Section 4*
Crankshaft design

4.1 Scope

4.1.1 The formulae given in this Section are applicable to solid or semi-built crankshafts, having a main support bearing adjacent to each crankpin, and are intended to be applied to a single crankthrow analysed by the static determinate method.

4.1.2 Alternative methods, including a fully documented stress analysis, will be considered.

4.1.3 Calculations are to be carried out for the maximum continuous power rating for all designed operating conditions. Calculations are to include short term high power operation where applicable.

4.1.4 Designs of crankshafts not included in this scope will be subject to special consideration.

4.1.5 The requirements of Section 4 apply to engines of powers greater that 110kW intended for Mobility or Ship Type systems.

4.2 Information to be submitted

4.2.1 In addition to detailed dimensioned plans, the following information is required to be submitted:

- Engine type – 4SCSA/2SCSA/in-line/vee.
- Output power at maximum continuous rating (MCR), in kW.
- Output speed at maximum continuous power, in rpm.
- Maximum cylinder pressure, in bar g.

- Mean indicated pressure, in bar g.
- Cylinder air inlet pressure, in bar g.
- Digitised gas pressure/crank angle cycle for MCR.
- Maximum pressure/speed relationship.
- Compression ratio.
- Vee angle and firing interval (if applicable), in degrees.
- Firing order numbered from driving end.
- Cylinder diameter, in mm.
- Piston stroke, in mm.
- Mass of connecting rod (including bearings), in kg.
- Centre of gravity of connecting rod from large end centre, in mm.
- Radius of gyration of connecting rod, in mm.
- Length of connecting rod between bearing centres, in mm.
- Mass of single crankweb (indicate if webs either side of pin are of different mass values), in kg.
- Centre of gravity of crankweb mass from shaft axis, in mm.
- Mass of counterweights fitted (for complete crankshaft) indicate positions fitted, in kg.
- Centre of gravity of counterweights (for complete crankshaft) measured from shaft axis, in mm.
- Mass of piston (including piston rod and crosshead where applicable), in kg.
- All individual reciprocating masses acting on one crank, in kg.
- Material specification(s).
- Specified minimum UTS, in N/mm^2.
- Specified minimum yield strength, in N/mm^2.
- Method of manufacture.
- Details of fatigue enhancement process (if applicable).
- For semi-built crankshafts – minimum and maximum diametral interference, in mm.

4.3 Symbols

4.3.1 For the purposes of this Chapter the following symbols apply (*see also Figure 1.4.1 Crank dimensions necessary for the calculation of stress concentration factors*):

h = radial thickness of web, in mm

k_e = bending stress factor

B = transverse breadth of web, in mm

D_p, D_j = outside diameter of pin or main journal, in mm

D_{pi}, D_{ji} = internal diameter of pin or main journal, in mm

D_s = shrink diameter of main journal in web, in mm

d_o = diameter of radial oil bore in crankpin, in mm

F = alternating force at the web centreline, in N

K_1 = fatigue enhancement factor due to manufacturing process

K_2 = fatigue enhancement factor due to surface treatment

M_b = alternating bending moment at web centreline, in N-mm (Note: alternating is taken to be ½ range value)

M_{BON} = alternating bending moment calculated at the outlet of crankpin oil bore

M_p, M_j = undercut of fillet radius into web measured from web face, in mm

R_p, R_j = fillet radius at junction of web and pin or journal, in mm

S = stroke, in mm

T = axial thickness of web, in mm

T_a = alternating torsional moment at crankpin or crank journal, in N-mm (Note: alternating is taken to be $^1/_2$ range value)

U = pin overlap

α_B = bending stress concentration factor for crankpin

α_T = torsional stress concentration factor for crankpin

β_B = bending stress concentration factor for main journal

β_Q = direct shear stress concentration factor for main journal

β_T = torsional stress concentration factor for main journal

γ_B = bending stress concentration factor for radially drilled oil hole in the crankpin

γ_T = torsional stress concentration factor for radially drilled oil hole in the crankpin

σ_{ax} = alternating axial stress, in N/mm^2

σ_b = alternating bending stress, in N/mm^2

σ_{BON} = alternating bending stress in the outlet of the oil bore, in N/mm^2

σ_p, σ_j = maximum bending stress in pin and main journal taking into account stress raisers, in N/mm^2

σ_{BO} = maximum bending stress in the outlet of the oil bore, in N/mm^2

σ_u = specified minimum UTS of material, in N/mm^2

σ_y = specified minimum yield stress of material, in N/mm^2

σ_Q = alternating direct stress, in N/mm^2

τ_a = alternating torsional stress, in N/mm^2

τ_p, τ_j = maximum torsional stress in pin and main journals taking into account stress raisers, in N/mm^2.

τ_{ob} = maximum torsional stress in outlet of crankpin oil bore taking into account stress raisers, in N/mm^2.

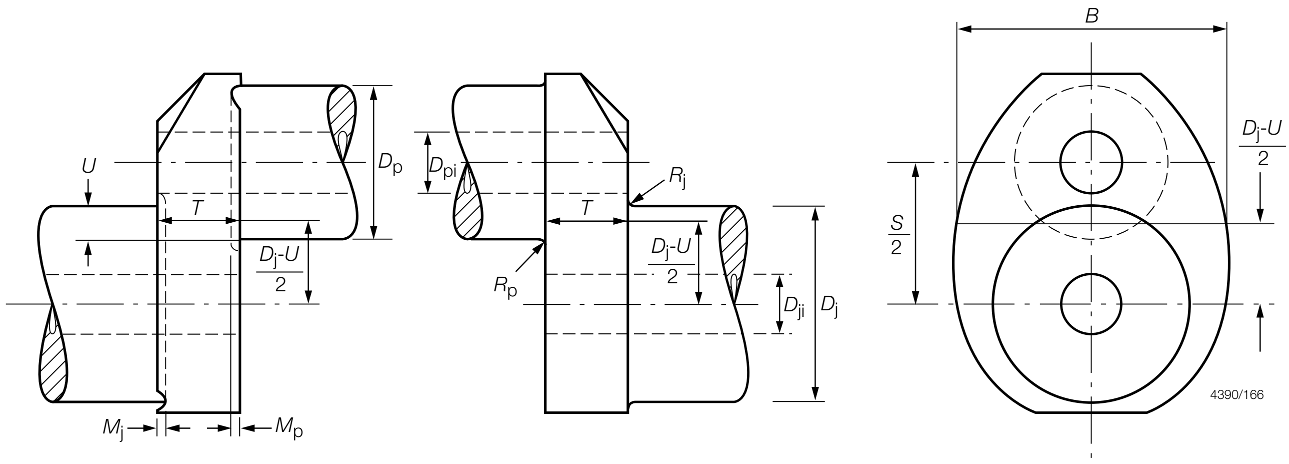


Figure 1.4.1 Crank dimensions necessary for the calculation of stress concentration factors

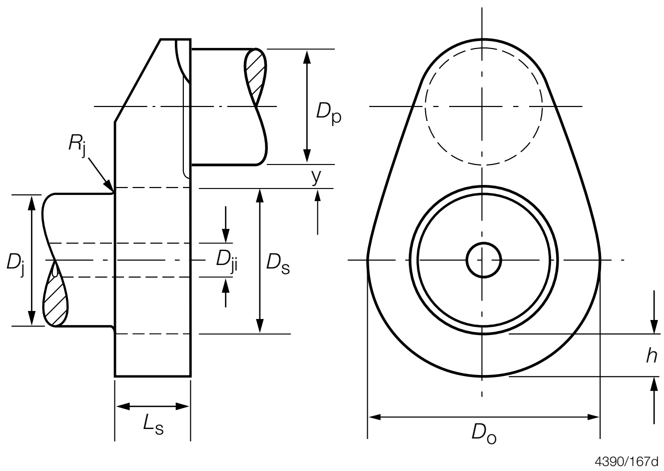


Figure 1.4.2 Crank dimensions for crankshaft without overlap

4.4 Stress concentration factors

4.4.1 **Geometric factors**. Crankshaft variables to be used in calculating the geometric stress concentrations together with their limits of applicability are shown in *Table 1.4.1 Crankshaft variables*.

Table 1.4.1 Crankshaft variables

Variable	Range	
	Lower	Upper
$b = B/D_p$	1,10	2,20
$d_j = D_{ji}/D_p$	0,00	0,80
$d_p = D_{pi}/D_p$	0,00	0,80
$m_j = M_j/D_p$	0,00	r_{jb}

$m_p = M_p/D_p$	0,00	r_p
$r_{jB} = R_j/D_p$	0,03	0,13
$r_{jT} = R_j/D_j$	0,03	0,13
$r_p = R_p/D_p$	0,03	0,13
$t = T/D_p$	0,20	0,80
$t = T_{red}/D_p$ *see* Note 3	0,20	0,80
$d = d_o/D_p$	0,00	0,20
$u = U/D_p$	–0,50	0,70

Note 1. Where variables fall outside the range, alternative methods are to be used and full details submitted for consideration.

Note 2. A lower limit of u can be extended down to large negative values provided that:
(i) If calculated $f(rec) < 1$ then the factor $f(rec)$ is not to be considered ($f(rec) = 1$)
(ii) If $u < -0.5$ then $f(ut)$ and $f(ru)$ are to be evaluated replacing actual value of u by –0,5.

Note 3. For crankshafts without overlap, *see also Vol 2, Pt 2, Ch 1, 4.4 Stress concentration factors 4.4.6*.

4.4.2 Crankpin stress concentration factors:

Bending

$$\alpha_B = 2{,}70\, f(ut).f(t).f(b).f(r).f(dp).f(dj).f(rec)$$

where

$f(ut) = 1{,}52 - 4{,}1t + 11{,}2t^2 - 13{,}6t^3 + 6{,}07t^4 - u\,(1{,}86 - 8{,}26t + 18{,}2t^2 - 18{,}5t^3 + 6{,}93t^4) - u^2\,(3{,}84 - 25{,}0t + 70{,}6t^2 - 87{,}0t^3 + 39{,}2t^4)$

$f(t) = 2{,}18t^{0{,}717}$

$f(b) = 0{,}684 - 0{,}0077b + 0{,}147b^2$

$f(r) = 0{,}208r_p^{(-0{,}523)}$

$f(dp) = 1 + 0{,}315(d_p) - 1{,}52(d_p)^2 + 2{,}41(d_p)^3$

$f(dj) = 1 + 0{,}27d_j - 1{,}02(d_j)^2 + 0{,}531(d_j)^3$

$f(rec) = 1 + (m_p + m_j)\,(1{,}8 + 3{,}2u)$

= valid only between $u = -0{,}5$ and $0{,}5$

Torsion

$$\alpha_T = 0{,}8\; f(ru).f(b).\,f(t)$$

where

$f(ru) = r_p^{-(0{,}22 + 0{,}1u)}$

$f(b) = 7{,}9 - 10{,}65b + 5{,}35b^2 - 0{,}857b^3$

$f(t) = t^{(-0{,}145)}$

4.4.3 Crank journal stress concentration factors (not applicable to semi-built crankshafts):

Bending

$$\beta_B = 2,71 f_B(ut).f_B(t).f_B(b).f_B(r).f_B(dj).f_B(dp).f(rec)$$

where

$f_B(ut)$ = $1,2 - 0,5t + 0,32t^2 - u\,(0,80 - 1,15t + 0,55t^2) - u^2\,(2,16 - 2,33t + 1,26t^2)$

$f_B(t)$ = $2,24t^{0,755}$

$f_B(b)$ = $0,562 + 0,12b + 0,118b^2$

$f_B(r)$ = $0,191 r_{jB}^{(-0,557)}$

$f_B(dj)$ = $1 - 0,644d_j + 1,23(d_j)^2$

$f_B(dp)$ = $1 - 0,19d_p + 0,0073(dp)^2$

$f(rec)$ = $1 + (m_p + m_j)\,(1,8 + 3,2u)$

= valid only between $u = -0,5$ and $0,5$

Direct shear

β_Q = $3,01 f_Q(u).\ f_Q(t).\ f_Q(b).\ f_Q(r).\ f_Q(dp).\ f(rec)$

where

$f_Q(u)$ = $1,08+0,88u-1,52(u)^2$

$f_Q(t)$ = $\dfrac{t}{0,0637 + 0,937t}$

$f_Q(b)$ = $b - 0,5$

$f_Q(r)$ = $0,533 r_{JB}{}^{(-0,204)}$

$f\,Q(dp)$ = $1-1,19d_p+1,74(d_p)^2$

$f(rec)$ = $1+(m_p+m_j)\,(1,8 + 3,2u)$

= valid only between $u = -0,5$ and $0,5$

Torsion where

$$\beta_T = 0,8(ru).\ f(b).\ f(t)$$

$f(ru)$ = $r_{jT}^{(-0,22+0,1u)}$

$f(b)$ = $7,9 - 10,65 + 5,35b^2 - 0,857b^3$

$f(t)$ = $t^{(-0,145)}$

4.4.4 Crankpin oil bore stress concentration factors for radially drilled oil holes:

- Bending

γ_B = $3 - 5,88 \bullet d_o + 34,6 \bullet d_o^2$

- Torsion

γ_T = $4 - 68 \bullet d_o + 30 \bullet d_o^2$

4.4.5 Where experimental measurements of the stress concentrations are available, these may be used. The full documented analysis of the experimental measurement is to be submitted for consideration.

4.4.6 In the case of semi-built crankshafts when $M_p > R_p$ the web thickness is to be taken as

T_{red} = $T - (M_p - R_p)$ and the web width B is to be taken in way of the crankpin fillet radius centre, *see Figure 1.4.2 Crank dimensions for crankshaft without overlap*.

4.5 Nominal stresses

4.5.1 The nominal alternating bending stress, σ_b, is to be calculated from the maximum and minimum bending moment at the web centreline taking into account all forces being applied to the crank throw in one working cycle with the crank throw simply supported at the mid length of the main journals.

4.5.2 Nominal bending stresses are referred to the web bending modulus.

4.5.3 Nominal alternating bending stress:

$$\sigma_b = \pm \frac{M_b}{Z_{web}} k_e \ \mathrm{N/mm^2}$$

where

Z_{web} = $\frac{BT^2}{6}$ mm^3

k_e = 0,8 for crosshead engines

= 1,0 for trunk piston engines

4.5.4 Nominal alternating bending stress, σ_{BON}, in the outlet of the crankpin oil bore, in N/mm^2:

$$\sigma_{BON} = \pm \frac{M_{BON}}{Z_{crankpin}}$$

Where

M_{BON} is taken as the 1/2 range value

M_{BON} = $\pm 1/2\ (M_{BOmax} - M_{BOmin})$

and

M_{BO} = $(M_{BTO} \cos\psi + M_{BRO} \sin\psi)$ *see Figure 1.4.3 Crankpin section through the oil bore*

The two relevant bending moments are taken in the crankpin cross-section through the oil bore.

M_{BRO} = bending moment of the radial component of the connecting-rod force

M_{BTO} = bending moment of the tangential component of the connecting-rod force

$Z_{crankpin}$ = $\frac{\pi}{32}\left[\frac{D^4 - d^4}{d}\right]$ with $Z_{crankpin}$ related to the cross-section of axially bored crankpin.

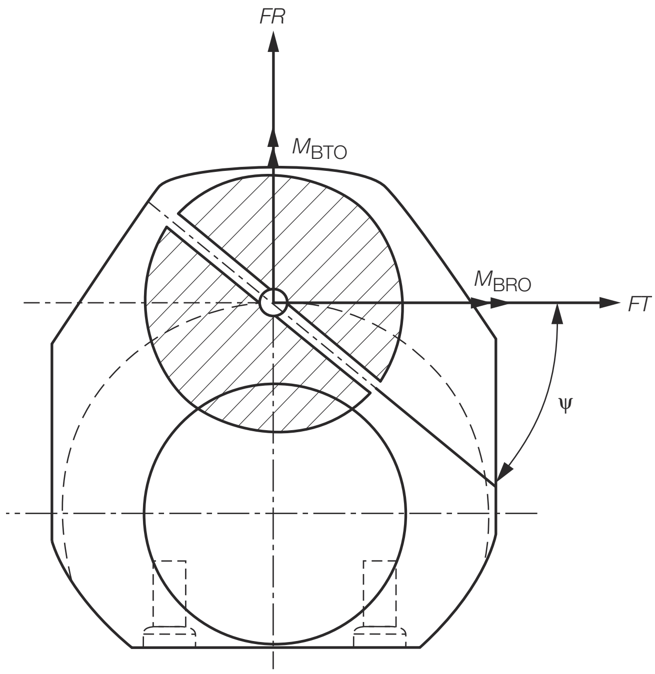


Figure 1.4.3 Crankpin section through the oil bore

4.5.5 The nominal direct shear stress in the web for the purpose of assessing the main journal is to be added algebraically to the bending stress, using the alternating forces which have been used in deriving M_{b} in *Vol 2, Pt 2, Ch 1, 4.5 Nominal stresses 4.5.3*.

4.5.6 Nominal stress is referred to the web cross-section area or the pin cross-section area as applicable.

4.5.7 Nominal alternating direct shear stress:

$$\sigma_{\text{Q}} = \pm \frac{F}{A_{\text{web}}} k_{\text{e}} \ \text{N/mm}^3$$

where

A_{web} = BT mm^2

4.5.8 The nominal alternating torsional stress, τ_{a}, is to be taken into consideration. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted.

4.5.9 The results of torsional vibration calculations for the full dynamic system, carried out in accordance with *Vol 2, Pt 5 Shaft Vibration and Alignment* are to be submitted.

4.5.10 Nominal alternating torsional stress:

$$\tau_{\text{a}} = \pm \frac{T_{\text{a}}}{Z_{\text{T}}} \text{N/mm}^2$$

where

Z_{T} = torsional modulus of crapkin and main journal

= $\pi \dfrac{\left(D^4 - d^4\right)}{16D} \text{mm}^3$

D = outside diameter of crankpin or main journal, in mm

d = inside diameter of crankpin or main journal, in mm

τ_a is to be ascertained from assessment of the torsional vibration calculations where the maximum and minimum torques are determined for every mass point of the complete dynamic system and for the entire speed range by means of a harmonic synthesis of the forced vibrations from the 1st order up to and including the 15th order for 2-stroke cycle engines and from the 0,5th order up to and including the 12th order for 4-stroke cycle engines. Whilst doing so, allowance must be made for the damping that exists in the system and for unfavourable conditions (misfiring in one of the cylinders when no combustion occurs but only compression cycle). The speed step calculation shall be selected in such a way that any resonance found in the operational speed range of the engine shall be detected.

If T_a is not known, a value can be calculated by the following formula as an approximation in the first instance:

$$T_\mathrm{a} = \left((18,6 - 0,0132 D_\mathrm{e}) \times \frac{\sigma_u + 160}{560} \right) \times Z_\mathrm{e} \ \mathrm{Nmm}$$

where

$$D_\mathrm{e} = D_\mathrm{j} \sqrt[3]{1 + \left(\frac{D_\mathrm{ji}}{D_\mathrm{j}} \right)^4}$$

$$or \qquad D_\mathrm{p} \sqrt[3]{1 - \left(\frac{D_\mathrm{pi}}{D_\mathrm{p}} \right)^4}$$

whichever is smaller

Z_e = corresponding torsional modulus

$$= \pi \frac{\left(D_e{}^4 - d^4 \right)}{16 D_e} \mathrm{mm}^3$$

4.5.11 For the purpose of the crankshaft assessment, the nominal alternating torsional stress considered in calculations is to be the highest calculated value, according to the method described in *Vol 2, Pt 2, Ch 1, 4.5 Nominal stresses 4.5.9*, occurring at the most torsionally loaded mass point of the crankshaft system.

4.5.12 The approval of the crankshaft will be based on the installation having the largest nominal alternating torsional stress (but not exceeding the maximum figure specified by the engine manufacturer). For each installation it is to be ensured by calculation that the maximum approved nominal alternating torsional stress is not exceeded.

4.5.13 Reference should be made to *Vol 2, Pt 5, Ch 1 Torsional Vibration* on the calculations of torsional vibration characteristics.

4.5.14 In addition to the bending stress, σ_b, the axial vibratory stress, σ_{ax}, is to be taken into consideration, for crosshead type engines. For trunk piston engines, $\sigma_{ax} = 0$. The value is to be derived from forced-damped vibration calculations of the complete dynamic system. Alternative methods will be given consideration. The engine designer is to advise the maximum level of alternating vibratory stress that is permitted. The corresponding crankshaft free-end deflection is also to be stated.

4.6 Maximum stress levels

4.6.1 Crankpin fillet:

Maximum alternating bending stress:

$$\sigma_\mathrm{p} = \alpha_\mathrm{B} (\sigma_\mathrm{b} + \sigma_\mathrm{ax}) \ \mathrm{N/mm}^2$$

where

α_B = bending stress concentration (*see Vol 2, Pt 2, Ch 1, 4.4 Stress concentration factors 4.4.2*)

Maximum alternating torsional stress:

$$\tau_p = \alpha_T \tau_{ax} \text{ N/mm}^2$$

where

α_T = torsional stress concentration (*see Vol 2, Pt 2, Ch 1, 4.4 Stress concentration factors 4.4.2*)

τ_a = nominal alternating torsional stress in crankpin N/mm^2.

4.6.2 Outlet of crankpin oil bore:

- Maximum alternating bending stress:

$$\sigma_{BO} = \gamma_B (\sigma_{BON} + \sigma_{ax}) \text{ N/mm}^2$$

where

γ_B = bending stress concentration factor, *see Vol 2, Pt 2, Ch 1, 4.4 Stress concentration factors 4.4.4*

- Maximum alternating torsional stress:

$$\tau_{tob} = \gamma_T \tau_a \text{ N/mm}^2$$

where

γ_T = torsional stress concentration factor, *see Vol 2, Pt 2, Ch 1, 4.4 Stress concentration factors 4.4.4*

τ_a = nominal alternating torsional stress in crankpin N/mm^2.

4.6.3 Crank journal fillet (not applicable to semi-built crankshafts).

Maximum alternating bending stress:

$$\sigma_j = \beta_B(\sigma_b + \sigma_{ax}) + \beta_Q \sigma_Q \text{ N/mm}^2$$

where

β_B = bending stress concentration (*see Vol 2, Pt 2, Ch 1, 4.4 Stress concentration factors 4.4.3*)

β_Q = direct stress concentration (*see Vol 2, Pt 2, Ch 1, 4.4 Stress concentration factors 4.4.3*)

Maximum alternating torsional stress:

$$\tau_j = \beta_T \tau_a \text{ N/mm}^2$$

where

β_T = torsional stress concentration (*see Vol 2, Pt 2, Ch 1, 4.4 Stress concentration factors 4.4.3*)

τ_a = nominal alternating torsional stress in main journal N/mm^2.

4.7 Equivalent alternating stress

4.7.1 Equivalent alternating stress of the crankpin, σ_{ep}, or crank journal σ_{ej}, is defined as:

$$\sigma_{epj} \sigma_{ej} = \sqrt{(\sigma + 10)^2 + 3\tau^2} \text{ N/mm}^2$$

where

σ = $\sigma_p$or σ_j N/mm^2

τ = τ_p or τ_j N/mm^2.

4.7.2 Equivalent alternating stress for the outlet of the crankpin oil bore σ_{eob}, is defined as:

$$\sigma_{eob} = \pm \frac{1}{3}\,\sigma_{bo}\left[1 + 2\sqrt{1 + \frac{9}{4}\left(\frac{\tau_{to}}{\sigma_{bo}}\right)^2}\,\right] \text{N/mm}^2$$

4.8 Fatigue strength

4.8.1 The fatigue strength of a crankshaft is based upon the crankpin and crank journal as follows:

$$\sigma_{fp} = K_1 K_2(0{,}42\sigma_u + 39{,}3)(0{,}264 + 1{,}073D_p^{-0{,}2} + \frac{785 - \sigma_u}{4900} + \frac{196}{\sigma_u}\sqrt{\frac{1}{R_p}}) \text{ N/mm}^2$$

To calculate the fatigue strength in the oil bore area, replace R_p with ½d_o and σ_{fp} with σ_{fob}

$$\sigma_{fj} = K_1 K_2(0{,}42\sigma_u + 39{,}3)(0{,}264 + 1{,}073D_j^{-0{,}2} + \frac{785 - \sigma_u}{4900} + \frac{196}{\sigma_u}\sqrt{\frac{1}{R_j}} \text{ N/mm}^2$$

where

σ_u = UTS of crankpin or crank journal as approriate, N/mm^2

K_1 = fatigue endurance factor appropriate to the manufacturing process

= 1,05 for continuous grain-flow (CGF) or die-forged

= 1,0 for freedom forged (without CGF)

= 0,93 for cast steel manufactured using a LR approved cold rolling process

K_2 = fatigue enhancement factor for surface treatment. These treatments are to be applied to the fillet radii.

4.8.2 A value for K_2 will be assigned upon application by the engine designers. Full details of the process, together with the results of full scale fatigue tests will be required to be submitted for consideration. Alternatively, the following values may be taken (surface hardened zone to include fillet radii):

K_2 = 1,15 for induction hardened

= 1,25 for nitrided

Where a value of K_1 or K_2 greater than unity is to be applied then details of the manufacturing process are to be submitted.

4.9 Acceptability criteria

4.9.1 The acceptability factor, Q, is to be greater than 1,15:

$Q = \dfrac{\sigma_f}{\sigma_e}$ for crankpin and journal and the outlet of crankpin oil bore

where

σ_f = σ_{fp} or σ_{fj} or σ_{ob}

σ_e = σ_{ep} or σ_{ej} or σ_{eob}.

4.10 Crankshaft oil hole

4.10.1 The junction of the oil hole with the crankpin or main journal surface is to be formed with an adequate radius and smooth surface finish down to a minimum depth equal to 1,5 times the oil bore diameter.

4.10.2 Fatigue strength calculations or, alternatively, fatigue test results may be required to demonstrate acceptability.

4.10.3 When journal diameter is equal or larger than the crankpin diameter, the outlets of main journal oil bores are to be formed in a similar way to the crankpin oil bores, otherwise separate fatigue strength calculations or, alternatively, fatigue test results may be required.

4.11 Shrink fit of semi-built crankshafts

4.11.1 The maximum permissible internal diameter in the journal pin is to be calculated in accordance with the following formula:

$$D_{ji} = D_s\sqrt{1 - \frac{4000 FoS\, M_{\max}}{\mu\ \pi\ D_s^{\ 2} L_s\, \sigma_{yj}}}\ \text{mm}$$

where the symbols are defined in *Vol 2, Pt 2, Ch 1, 4.11 Shrink fit of semi-built crankshafts 4.11.7*.

4.11.2 When *Vol 2, Pt 2, Ch 1, 4.11 Shrink fit of semi-built crankshafts 4.11.1* cannot be complied with, then *Vol 2, Pt 2, Ch 1, 4.11 Shrink fit of semi-built crankshafts 4.11.7* is not applicable. In such cases δ_{min} and δ_{max} are to be established from FEM calculations.

4.11.3 The following formulae are applicable to crankshafts assembled by shrinking main journals into the crankwebs.

4.11.4 In general, the radius of transition, R_j, between the main journal diameter, D_j, and the shrink diameter, D_s, is to be not less than $0{,}015D_j$ or $0{,}5(D_s - D_j)$.

4.11.5 The distance, y, between the underside of the pin and the shrink diameter should be greater than $0{,}05D_s$.

4.11.6 Deviations from these parameters will be specially considered.

4.11.7 The proposed diametral interference is to be within the following limits (*see also Figure 1.4.4 Crankthrow of semi-built crankshaft*):

The minimum required diametral interference is to be taken as the greater of:

$$\delta_{\min} = \frac{12,156 \times 10^6 (FoS)}{TD_s\ \mu E}\ \frac{P}{R}\ (1 + C)\ \frac{k^2 - l^2}{\left(k^2 - 1\right)\left(1 - l^2\right)}\ \text{mm}$$

or

$$= \quad \delta_{\min} = \frac{\sigma_{\mathrm{y}} D_{\mathrm{s}}}{E}\ \text{mm}$$

where

h = minimum radial thickness of the web around the diameter D_s, in mm

k = $\dfrac{D_{\mathrm{o}}}{D_{\mathrm{s}}}$

l = $\dfrac{D_{\mathrm{ji}}}{D_{\mathrm{s}}}$

C = ratio of torsional vibratory torque to the mean transmitted torque at the *P/R* rating being considered

D_o = $D_s + 2h$, in mm

E = Young's modulus of elasticity of crankshaft material, N/mm^2

FoS = Factor of Safety against rotational slippage to be taken as 2,0. A value less than 2,0 may be used where documented by experiments to demonstrate acceptability

P = output power, in kW

R = speed at associated power, in rpm

T = crankweb thickness, in mm

μ = coefficient of static friction to be taken as 0,2 for degreased surfaces provided T/D_s > 0,4. A value greater than 0,2 may be used where documented by experiments to demonstrate acceptability

σ_{yj} = minimum yield strength of material for journal pin

M_{max} = absolute maximum value of the torque taking *Vol 2, Pt 5, Ch 1 Torsional Vibration* into consideration

L_s = length of shrink fit, in mm

Maximum diametral interference, δ_{max}, is not to be greater than:

$$\delta_{max} = \frac{\sigma_y D_s}{E} + \frac{0,8D_s}{1000}\, mm.$$

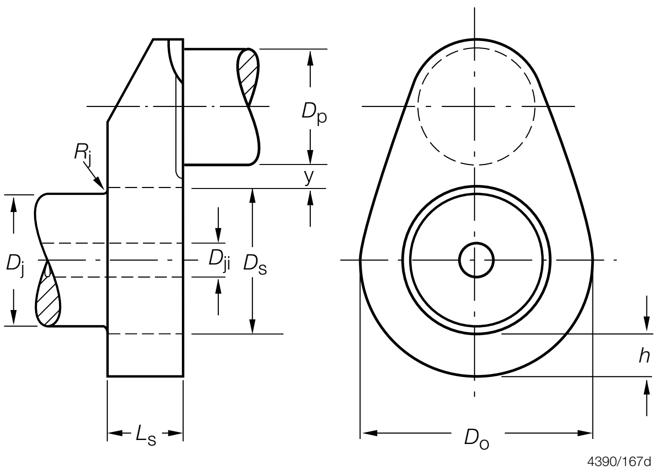


Figure 1.4.4 Crankthrow of semi-built crankshaft

4.11.8 Reference marks are to be provided on the outer junction of the crankwebs with the journals.

4.12 Alternative method for calculation of stress concentration factors

4.12.1 LR will give consideration to crankshaft design using an alternative method given in LR's *ShipRight procedures for alternative method for calculation of stress concentration factors in the web fillet radii of crankshafts by utilising Finite Element*.

■ Section 5
Construction and welded structures

5.1 Crankcases

5.1.1 Crankcases and their doors are to be of robust construction to withstand anticipated crankcase pressures that may arise during a crankcase explosion taking into account the installation of explosion relief valves required by *Vol 2, Pt 2, Ch 1, 6 Safety arrangements on engines* The doors are to be securely fastened so that they will not be readily displaced by a crankcase explosion.

5.2 Welded joints

5.2.1 Bedplates and major components of engine structures are to be made with a minimum number of welded joints.

5.2.2 Double welded butt joints are to be adopted wherever possible in view of their superior fatigue strength.

5.2.3 Girder and frame assemblies should, so far as possible, be made from one plate or slab, shaped as necessary, rather than by welding together a number of small pieces.

5.2.4 Steel castings are to be used for parts which would otherwise require complicated weldments.

5.2.5 Care is to be taken to avoid stress concentrations such as sharp corners and abrupt changes in section.

5.2.6 Joints in parts of the engine structure which are stressed by the main gas or inertia loads are to be designed as continuous full strength welds and for complete fusion of the joint. They are to be so arranged that, in general, welds do not intersect, and that welding can be effected without difficulty and adequate inspection can be carried out. Abrupt changes in plate section are to be avoided and where plates of substantially unequal thickness are to be butt welded, the thickness of the heavier plate is to be gradually tapered to that of the thinner plate. Tee joints are to be made with full bevel or equivalent weld preparation to ensure full penetration.

5.2.7 In single plate transverse girders the castings for main bearing housings are to be formed with web extensions which can be butt welded to the flange and vertical web plates of the girder. Stiffeners in the transverse girder are to be attached to the flanges by full penetration welds.

5.3 Materials and construction

5.3.1 All welded construction is to be in accordance with the requirements specified in *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

5.3.2 Plates, sections, forgings and castings are to be of welding quality in accordance with the requirements of *Rules for the Manufacture, Testing and Certification of Materials, July 2015*, and with a carbon content generally not exceeding 0,23 per cent. Steels with higher carbon contents may be approved subject to satisfactory results from welding procedure tests.

5.3.3 Plates and weld preparations are to be accurately machined or flame-cut to shape. Flame-cut surfaces are to be cleaned by machining or grinding; if the flame-cut surfaces are smooth, wire brushing may be accepted.

5.3.4 Before welding is commenced the component parts of bedplates and framework are to be accurately fitted and aligned.

5.3.5 The welding is to be carried out in positions free from draughts and is to be downhand (flat) wherever practicable. Welding consumables are to be suitable for the materials being joined. Preheating is to be adopted when heavy plates or sections are welded. The finished welds are to have an even surface and are to be free from undercutting.

5.3.6 Welds attaching bearing housings to the transverse girders are to have a smooth contour and, if necessary, are to be made smooth by grinding.

5.4 Post-weld heat treatment

5.4.1 Bedplates are to be given a stress relieving heat treatment except engine types where the bedplate as a whole is not subjected to direct loading from the cylinder pressure. For these types, only the transverse girder assemblies need be stress relieved.

5.4.2 Stress relieving is to be carried out by heating the welded structure uniformly and slowly to a temperature between 580°C and 620°C, holding that temperature for not less than one hour per 25 mm of maximum plate thickness and thereafter allowing the structure to cool slowly in the furnace.

5.4.3 Omission of post-weld heat treatment of bedplates and their sub-assemblies will be considered on application by the engine builder with supporting evidence in accordance with *Ch 13, 2.10 Post-weld heat treatment 2.10.4* of the Rules for Materials.

5.5 Inspection

5.5.1 Welded engine structures are to be examined during fabrication, special attention being given to the fit of component parts of major joints prior to welding.

5.5.2 On completion of welding and stress relief heat treatment, all welds are to be examined.

5.5.3 Welds in transverse girder assemblies are to be crack detected by an approved method to the satisfaction of the Surveyors. Other joints are to be similarly tested if required by the Surveyors.

■ *Section 6*
Safety arrangements on engines

6.1 Relief valves

6.1.1 Scavenge spaces in open connection with cylinders are to be provided with explosion relief valves. The valves are to be arranged and positioned on engines to minimise the possibility of danger and damage arising from emission from the valves.

6.1.2 Crankcases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices, to relieve the crankcases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0,2 bar. Crankcase relief valves are to be type tested in accordance with *Vol 2, Pt 2, Ch 1, 12 Type Testing – General*.

6.1.3 The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

6.1.4 Each valve is to be fitted with a flame arrester that permits flow for crankcase pressure relief and prevents the passage of flame following a crankcase explosion. The valves are to be type tested in a configuration that represents the installation arrangements that will be used on an engine and in accordance with *Vol 2, Pt 2, Ch 1, 12 Type Testing – General*. The valves are to be positioned on engines to minimise the possibility of danger and damage arising from emission of the crankcase atmosphere. Where shielding from the emissions is fitted to a valve, the valve is to be tested to demonstrate that the shielding does not adversely affect the operational effectiveness of the valve.

6.1.5 The valves are to be provided with a copy of the manufacturer's installation and maintenance manual that is pertinent to the size and type of valve being supplied for installation on a particular engine. The manual is to contain the following information:

(a) Description of valve with details of function and design limits.
(b) Copy of type test certification.
(c) Installation instructions.
(d) Maintenance in service instructions to include testing and renewal of any sealing arrangements.
(e) Actions required after a crankcase explosion.

6.1.6 A copy of the installation and maintenance manual required by *Vol 2, Pt 2, Ch 1, 6.1 Relief valves 6.1.5* is to be provided on board ship.

6.1.7 Plans showing details and arrangements of the relief valves are to be submitted for approval. *see 2.1*

6.1.8 The valves are to be provided with suitable markings that include the following information:

(a) Name and address of manufacturer.
(b) Designation and size.
(c) Month/Year of manufacture.
(d) Approved installation orientation.

6.2 Number of relief valves

6.2.1 Internal combustion engines having a cylinder bore of 200 mm and above or a crankcase volume of 0,6 m^3 and above shall be provided with crankcase explosion relief valves.

6.2.2 In engines having cylinders exceeding 200 mm but not exceeding 250 mm bore, at least two relief valves are to be fitted; each valve is to be located at or near the ends of the crankcase. Where the engine has more than eight crank throws an additional valve is to be fitted near the centre of the engine.

6.2.3 In engines having cylinders exceeding 250 mm but not exceeding 300 mm bore, at least one relief valve is to be fitted in way of each alternate crank throw with a minimum of two valves. For engines having 3, 5, 7, 9, etc. crank throws, the number of relief valves is not to be less than 2, 3, 4, 5, etc. respectively.

6.2.4 In engines having cylinders exceeding 300 mm bore, at least one valve is to be fitted in way of each main crank throw.

6.2.5 Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear or chaincases for camshaft or similar drives, when the gross volume of such spaces exceeds 0,6 m^3.

6.3 Size of relief valves

6.3.1 The combined free area of the crankcase relief valves fitted on an engine is to be not less than 115 cm^2/m^3 based on the volume of the crankcase.

6.3.2 The free area of each relief valve is to be not less than 45 cm^2.

6.3.3 The free area of the relief valve is the minimum flow area at any section through the valve when the valve is fully open.

6.3.4 In determining the volume of the crankcase for the purpose of calculating the combined free area of the crankcase relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crankcase. The volume of the rotating and reciprocating components are to be included.

6.4 Vent pipes

6.4.1 Through ventilation of crankcase, and any arrangement which could produce a flow of external air within the crankcase, is in principle not permitted except for dual fuel engines where crankcase ventilation is to be provided. Where crankcase vent pipes are fitted, they are to be made as small as practicable to minimise the inrush of air after an explosion. Vents from crankcases of main engines are to be led to a safe position on deck or other approved position.

6.4.2 If provision is made for the extraction of gases from within the crankcase, e.g. for oil mist detection purposes, the vacuum within the crankcase is not to exceed 25 mm of water.

6.4.3 Lubricating oil drain pipes from engine sump to drain tank are to be submerged at their outlet ends. Where two or more engines are installed, vent pipes, if fitted, and lubrication oil drain pipes are to be independent to avoid intercommunication between crankcases.

6.5 Warning notice

6.5.1 A warning notice is to be fitted in a prominent position, preferably on a crankcase door on each side of the engine, or alternatively at the engine room control station. This warning notice is to specify that whenever overheating is suspected in the crankcase, the crankcase doors or sight holes are not to be opened until a reasonable time has elapsed after stopping the engine, sufficient to permit adequate cooling within the crankcase.

6.6 Crankcase access and lighting

6.6.1 Where access to crankcase spaces is necessary for inspection purposes, suitably positioned rungs or equivalent arrangements are to be provided as considered appropriate.

6.6.2 When interior lighting is provided it is to be flameproof (Ex 'd') in relation to the interior and details are to be submitted for approval, *see also Vol 2, Pt 9, Ch 3, 9 Equipment – heating, lighting and accessories*. No wiring is to be fitted inside the crankcase.

6.7 Fire extinguishing system for scavenge manifolds

6.7.1 Crosshead type engine scavenge spaces in open connection with cylinders are to be provided with approved fixed or portable fire extinguishing arrangements which are to be independent of the fire extinguishing system of the engine room.

6.8 Oil mist detection

6.8.1 Where crankcase oil mist detection/monitoring arrangements are fitted, they are to be of a type approved by LR, tested in accordance with *Vol 2, Pt 2, Ch 1, 12 Type Testing – General* and comply with *Vol 2, Pt 2, Ch 1, 6.8 Oil mist detection 6.8.8* to *Vol 2, Pt 2, Ch 1, 6.8 Oil mist detection 6.8.15*.

6.8.2 The oil mist detection system and arrangements are to be installed in accordance with the engine designer's and oil mist manufacturer's instructions/recommendations. The following particulars are to be included in the instructions:

(a) Schematic layout of engine oil mist detection and alarm system showing locations of engine crankcase sample points and cabling/piping arrangements together with pipe dimensions to detector.
(b) Evidence of study to justify the selected location of sample points and sample extraction rate (if applicable) in consideration of the crankcase arrangements and geometry and the predicted crankcase atmosphere where oil mist can accumulate.
(c) The manufacturer's maintenance and test manual.
(d) Information relating to type or in-service testing of the engine with engine protection system test arrangements having approved types of oil mist detection equipment.

6.8.3 A copy of the oil mist detection equipment maintenance and test manual required by *Vol 2, Pt 2, Ch 1, 6.8 Oil mist detection 6.8.2* is to be provided on board ship.

6.8.4 Oil mist detection and alarm information is to be capable of being read from a safe location away from the engine.

6.8.5 In the case of multi engine installations, each engine is to be provided with individual, dedicated oil mist detection arrangements and alarm(s).

6.8.6 Oil mist detection and alarm systems are to be capable of being tested on the test bed and on board when the engine is at a standstill and when the engine is running at normal operating conditions in accordance with test procedures that are acceptable to LR.

6.8.7 Alarms and safeguards for the oil mist detection system are to be in accordance with *Vol 2, Pt 9 Electrotechnical Systems* as applicable.

6.8.8 The oil mist detection arrangements are to provide an alarm indication in the event of a foreseeable functional failure in the equipment and installation arrangements. *See Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding 2.4.5*.

6.8.9 The oil mist detection system is to provide an indication that any lenses fitted in the equipment and used in determination of the oil mist level have been partially obscured to a degree that will affect the reliability of the information and alarm indication.

6.8.10 Where oil mist detection equipment includes the use of programmable electronic systems, the arrangements are to be in accordance with *Vol 2, Pt 9 Electrotechnical Systems* as applicable.

6.8.11 Schematic layouts showing details and arrangements of oil mist detection and alarm systems are to be submitted. *See 2.1*.

6.8.12 The equipment together with detectors is to be tested when installed on the test bed and on board ship to demonstrate that the detection and alarm system functions correctly. The testing arrangements are to be to the satisfaction of the Surveyor.

6.8.13 Where sequential oil mist detection arrangements are provided, the sampling frequency and time is to be as short as reasonably practicable.

6.8.14 Where engine bearing temperature monitors or alternative methods are provided for the prevention of the build up of oil mist that may lead to a potentially explosive condition within the crankcase, detailed information is to be submitted for consideration. The information is to include:

(a) Engine particulars - type, power, speed, stroke, bore and crankcase volume.
(b) Details of arrangements designed to prevent the build up of potentially explosive conditions within the crankcase, e.g. bearing temperature monitoring, oil splash temperature monitoring, crankcase pressure monitoring, and recirculation arrangements.
(c) Evidence to demonstrate that the arrangements are effective in preventing the build up of potentially explosive conditions together with details of in-service experience.
(d) Operating instructions and the maintenance and test instructions.

6.8.15 Where it is proposed to use the introduction of inert gas into the crankcase to minimise a potential crankcase explosion, details of the arrangements are to be submitted for consideration.

6.9 Emergency operation

6.9.1 Engines and their service systems are to be capable of operation for a period of not less than eight hours when the engine compartment is flooded by sea-water to a mean level corresponding to the height of the lowest part of the engines' crankshaft main bearing journals with the ship in the most limiting trim.

■ *Section 7*
Starting arrangements

7.1 Air starting

7.1.1 Air starting arrangements are to meet the requirements of *Vol 2, Pt 7, Ch 3, 12 Air compressors and air starting arrangements*.

7.2 Electrical starting arrangements

7.2.1 Where main engines are fitted with electric starters, two batteries are to be fitted. Each battery is to be capable of starting the engines when cold and the combined capacity is to be sufficient without recharging to provide the number of starts of the main engines as required by *Vol 2, Pt 7, Ch 3, 12 Air compressors and air starting arrangements*. In other respects batteries are to comply with the requirements of *Vol 2, Pt 9, Ch 2, 7 Batteries*.

7.2.2 Electric starting arrangements for auxiliary engines are to have two separate batteries or be supplied by separate circuits from the main engine batteries when such are provided. Where one of the auxiliary engines only is fitted with an electric starter one battery will be acceptable.

7.2.3 The combined capacity of the batteries for starting the auxiliary engines is to be sufficient for at least three starts for each engine.

7.2.4 Engine starting batteries are to be used only for the purposes of starting the engines and for the engines' own control, alarm, monitoring and safety arrangements. Means are to be provided to ensure that the stored energy in the batteries is maintained at a level required to start the engines as defined in *Vol 2, Pt 2, Ch 1, 7.2 Electrical starting arrangements 7.2.1* and *Vol 2, Pt 2, Ch 1, 7.2 Electrical starting arrangements 7.2.3*.

7.2.5 Where engines are fitted with electric starting batteries, an alarm is to be provided for low battery change level.

7.2.6 Transient electrical loads due to starting of engines are not to interfere with power supplies to control and weapons systems.

7.2.7 The requirements for battery installations are given in *Vol 2, Pt 9 Electrotechnical Systems*.

7.3 Starting of the emergency source of power

7.3.1 Emergency generators are to be capable of being readily started in their cold conditions down to a temperature of 0ºC. If this is impracticable, or if lower temperatures are likely to be encountered, consideration is to be given to the provision and maintenance of heating arrangements, so that ready starting will be assured.

7.3.2 Each emergency generator that is arranged to be automatically started is to be equipped with an approved starting system having two independent sources of stored energy, each of which is sufficient for at least three consecutive starts. When hand (manual) starting is demonstrated to be effective, only one source of stored energy need be provided. However, this source of stored energy is to be protected against depletion below the level required for starting.

7.3.3 Provision is to be made to maintain continuously the stored energy at all times, and for this purpose:

(a) Electrical and hydraulic starting systems are to be maintained from the emergency switchboard.
(b) Compressed air starting systems may be maintained by the main or auxiliary compressed air receivers, through a suitable non-return valve, or by an emergency air compressor energised by the emergency switchboard.
(c) All these starting, charging and energy storing devices are to be located in the emergency generator room. These devices are not to be used for any purpose other than the operation of the emergency generator.

7.3.4 Electronically controlled emergency engines are to comply with the additional requirements of *Vol 2, Pt 2, Ch 1, 13.5 Emergency engines*.

7.3.5 When automatic starting is not required by the Rules and where it can be demonstrated as being effective, hand (manual) starting is permissible, such as manual cranking, inertial starters, manual hydraulic accumulators, powder charge cartridges.

7.3.6 When hand (manual) starting is not practicable, the provisions of *Vol 2, Pt 2, Ch 1, 7.3 Starting of the emergency source of power 7.3.2* and *Vol 2, Pt 2, Ch 1, 7.3 Starting of the emergency source of power 7.3.3* are to be complied with except that starting may be manually initiated.

7.3.7 Electric starting arrangements are to also satisfy *Vol 2, Pt 2, Ch 1, 7.2 Electrical starting arrangements 7.2.2*.

7.4 Engine control, alarm, monitoring and safety system power supplies

7.4.1 Power supplies are to be arranged so that power for electrically powered control, alarm, monitoring and safety systems required for engine starting and operation will remain available in the event of a failure. Power is to remain available to permit starting attempts for the number of starts specified by this Section for each individual source of stored energy.

7.4.2 Where adequate battery and charging capacity exists, an engine-starting battery may be used as one source of electrical power required by *Vol 2, Pt 2, Ch 1, 8.2 Intake and exhaust systems 8.2.6*.

7.4.3 An alarm is to be activated in the event of failure of a power supply and, where applicable, low battery charge level. Manual power supply changeover facilities are permitted.

■ *Section 8* **Piping**

8.1 Oil fuel, hydraulic and high-pressure oil systems

8.1.1 Oil fuel and hydraulic oil piping systems are to comply with *Vol 2, Pt 7, Ch 1 Piping Design Requirements* and *Vol 2, Pt 2, Ch 3 Steam Turbines* as applicable.

8.1.2 Engine fuel system components are to be designed to accommodate the maximum peak pressures experienced in service. Where fuel injection pumps are fitted, this applies in particular to the fuel injection pump supply and spill line piping which may be subject to high-pressure pulses from the pump. Connections on such piping systems should be chosen to minimise the risk of pressurised oil fuel leaks.

8.1.3 Where pumps are essential for engine operation, not less than two fuel oil and two hydraulic oil pressure pumps are to be provided for their respective service and arranged such that failure of one pump does not render the other inoperative. Each fuel oil pump and hydraulic oil pump is to be capable of supplying the quantity of oil for engine operation at its maximum continuous rating and arranged ready for immediate use.

8.1.4 All external high pressure fuel delivery piping between the fuel injection pump or high pressure fuel pumps and the fuel injectors is to be protected with a jacketed piping system capable of containing leakage and/or spray of flammable fluid from a high pressure line failure. The jacketed piping arrangements are to be approved, *see Table 1.2.1 Plans and particulars to be submitted*.

8.1.5 The protection required by *Vol 2, Pt 2, Ch 1, 8.1 Oil fuel, hydraulic and high-pressure oil systems 8.1.4* is to prevent fuel oil or fuel oil mist from reaching a source of ignition on the engine or its surroundings. Suitable drainage arrangements are to be made for draining any fuel oil leakage to one or more collector tank(s) fitted in a safe position and for preventing contamination of lubricating oil by fuel oil. An alarm is to be provided to indicate that leakage is taking place. The collector tank arrangement is to be approved.

8.1.6 The hydraulic oil pressure piping between the high pressure hydraulic pumps and hydraulic actuators is to be protected with a jacketed piping system or suitable enclosure capable of containing hydraulic oil leakage from a high pressure pipe failure. Where flammable oils are used in high-pressure systems to operate exhaust valves, the oil pipe lines between the highpressure oil pump and actuating oil pistons are to be protected with a jacketed piping system capable of preventing oil spray from a high-pressure line failure.

8.1.7 All lubricating and hydraulic oil pipes and oil fuel pipes that are not jacketed nor suitably enclosed are to be suitably installed and screened to avoid oil spray or leakage onto hot surfaces, *see also Vol 2, Pt 7, Ch 3, 2.9 Precautions against fire 2.9.4* and *Vol 2, Pt 7, Ch 5, 11.10 Precautions against fire 11.10.2* as applicable.

8.1.8 Where flammable oils are used in high-pressure actuating systems, a fatigue analysis is to be carried out in accordance with a suitable standard and all anticipated pressure, pulsation and vibration loads are to be considered. The analysis is to demonstrate that the design and arrangements are such that the likelihood of failure is as low as reasonably practicable. The analysis is to identify all assumptions made and standards to be applied during manufacture and testing. Any potential weak points that may develop due to incorrect construction or assembly are also to be identified.

8.1.9 Accumulators and associated high pressure piping are to be designed, manufactured and tested in accordance with a standard applicable to the maximum pressure and temperature rating of the system.

8.1.10 Where multi-engined installations are supplied from the same fuel source, means of isolating the fuel supply and spill piping to individual engines is to be provided. These means of isolation are not to affect the operation of the other engines and are to be operable from a position not rendered inaccessible by a fire on any of the engines, *see also Vol 2, Pt 1, Ch 3, 4.15 Stopping of machinery*.

8.1.11 For high pressure oil containing and mechanical power transmission systems, the quality plan for sourcing, design, installation and testing of components is to address the following issues (*see Table 1.2.1 Plans and particulars to be submitted*, Note 11):

(a) Design and manufacturing standard(s) applied.
(b) Materials used for construction of key components and their sources.
(c) Details of the quality control system applied during manufacture and testing.
(d) Details of type approval, type testing or approved type status assigned to the machinery or equipment.
(e) Details of installation and testing recommendations for the machinery or equipment.

8.1.12 Means are to be provided safely to purge the fuel oil system of air.

8.1.13 Short lengths of synthetic rubber hoses that comply with the requirements of *Vol 2, Pt 7, Ch 1, 13 Flexible hoses* may be used to accommodate relative movement between machinery and fixed piping systems.

8.2 Intake and exhaust systems

8.2.1 Where the surface temperature of the exhaust pipes and silencer may exceed 220°C, they are to be water cooled or efficiently lagged to minimise the risk of fire and to prevent damage by heat. Where lagging covering the exhaust piping system including flanges is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement could not occur, the lagging need not be encased.

8.2.2 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back to the engine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard. Erosion/ corrosion resistant shut-off flaps or other devices are to be fitted on the hull side shell or pipe end and acceptable arrangements made to prevent water flooding the space or entering the engine exhaust manifold.

8.2.3 Where the exhausts of two or more engines are led to a common silencer or exhaust gas-heated boiler or economiser, an isolating device is to be provided in each exhaust pipe.

8.2.4 For alternatively fired furnaces of boilers using exhaust gases and oil fuel, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby oil fuel can only be supplied to the burners when the isolating device is closed to the boiler.

8.2.5 In two-stroke main engines fitted with exhaust gas turbochargers which operate on the impulse system, provision is to be made to prevent broken piston rings entering the turbine casing and causing damage to blades and nozzle rings.

8.2.6 The air intakes and exhausts are to be in accordance with the engine manufacturer's design and installation requirements. Particular attention is drawn to the requirements on pressure and flow conditions to be achieved throughout the intake and exhaust systems. The arrangements are to comply with *Vol 2, Pt 2, Ch 1, 8.2 Intake and exhaust systems 8.2.7* as applicable.

8.2.7 Engine intakes are to be arranged to provide sufficient air to the engines whilst minimising the ingestion of harmful particles.

8.2.8 Each engine is to have an independent exhaust system.

8.2.9 The arrangement of the exhaust system is to be such as to prevent exhaust gases being drawn into the manned spaces, air conditioning systems and air intakes. They should not discharge into air cushion intakes.

8.2.10 The design of exhaust systems is to prevent deterioration of engine parts resulting from ingress of sea or rain water via the exhaust ducting when the engine is not in use. Drainage arrangements are to be provided and are to be led to a tank suitable for the potentially corrosive nature of any drainage.

8.2.11 Exhaust systems are not to pass through accommodation spaces.

8.2.12 The exhaust system is to accommodate thermal expansion and movement of the duct due to the combined effects of operating the engines and flexure of the ship's structure.

8.2.13 The exhaust ducting and silencers are to be designed and installed to minimise the risk of unburnt fuel collecting inside the duct.

8.2.14 The design of the exhaust ducting and associated equipment is to minimise the risk of soot collecting at any point other than those specifically intended for soot removal. Inspection and access openings are to be provided.

8.2.15 Plastic pipes intended for exhaust systems are to be in accordance with a recognised Code or Standard suitable for the intended service conditions.

8.3 Starting air pipe systems and safety fittings

8.3.1 Air start piping systems are, in general, to comply with the requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements*, with due regard being paid to the particular type of installation.

8.3.2 In designing the compressed air installation, care is to be taken that the compressor air inlets will be located in an atmosphere reasonably free from oil vapour or, alternatively, an air duct from outside the machinery space is to be led to the compressors.

8.3.3 The air discharge pipe from the compressors is to be led direct to the starting air receivers. Provision is to be made for intercepting and draining oil and water in the air discharge for which purpose a separator or filter is to be fitted in the discharge pipe between compressors and receivers.

8.3.4 The starting air pipe system from receivers to main and auxiliary engines is to be entirely separate from the compressor discharge pipe system. Stop valves on the receivers are to permit slow opening to avoid sudden pressure rises in the piping system. Valve chests and fittings in the piping system are to be of ductile material.

8.3.5 Drain valves for removing accumulations of oil and water are to be fitted on compressors, separators, filters and receivers. In the case of any low-level pipelines, drain valves are to be fitted to suitably located drain pots or separators.

8.3.6 The starting air piping system is to be protected against the effects of explosions by providing an isolating non-return valve or equivalent at the starting air supply to each engine.

8.3.7 In direct reversing engines, bursting discs or flame arresters are to be fitted at the starting valves on each cylinder; in non-reversing and auxiliary engines at least one such device is to be fitted at the supply inlet to the starting air manifold on each engine. The fitting of bursting discs or flame arresters may be waived in engines where the cylinder bore does not exceed 230 mm.

8.3.8 Alternative safety arrangements may be submitted for consideration.

8.4 Fuel oil filters and fittings

8.4.1 Two or more filters are to be fitted in the fuel oil supply lines to the main and auxiliary engines, and the arrangements are to be such that any filter can be cleaned without interrupting the supply of filtered fuel oil to the engines.

8.4.2 Drip trays are to be fitted under fuel oil filters and other fittings which are required to be opened up frequently for cleaning or adjustment or where there is the possibility of leakage. Alternative arrangements may be acceptable and full details should be submitted for consideration.

8.5 Lubricating oil systems

8.5.1 The lubrication system for each engine is to be independent from any other engine. A common lubricating oil storage tank arrangement may be provided.

8.5.2 Each engine is to be provided with a means of checking the running and static level of oil in the system/engine.

8.5.3 Means are to be provided to purge safely lubricating oil systems of air.

8.5.4 All vent pipes are to be arranged with a continuous upward slope of at least 10° to prevent the collection of oil in pockets and bends.

8.5.5 Oil sampling arrangements with the ability to take samples when the engine is running are to be fitted with valves or cocks of the self-closing type and located in positions as far removed as possible from any heated surface or electrical equipment.

8.6 Air induction systems

8.6.1 An air filter is to be fitted at the inlet to each engine. The air filters are to satisfy the following:

(a) Be readily removable for cleaning.
(b) Have an efficiency of not less than 98 per cent at 100 per cent of rated flow capacity when tested to an acceptable standard specified by the manufacturer.
(c) Be provided with an indicator, such as a pressure drop indicator, to indicate when a filter requires cleaning.
(d) Be of a design that does not degrade the performance of the engine.
(e) For engines drawing air from the engine compartment, be as close as possible to the engine air inlet and in such cases, the debris screen required by *Vol 2, Pt 2, Ch 1, 8.6 Air induction systems 8.6.4* may be omitted.

8.6.2 Where there is a requirement to provide a ducted air system to convey air from inlets on deck to the engine, the requirements of *Vol 2, Pt 2, Ch 1, 8.6 Air induction systems 8.6.3* to *Vol 2, Pt 2, Ch 1, 8.6 Air induction systems 8.6.6* are to be complied with.

8.6.3 The ducting is to be led by the most direct route practicable consistent with the arrangement of adjacent systems and equipment.

8.6.4 Each ducted air supply is to have the following:

(a) Means to prevent sea spray, aerosol salt and sand reaching the engine and means to remove any such substances that enter the intakes or their bypass arrangements. Suitable drainage arrangements to remove any water from intakes and intake bypass arrangements (where fitted) to guard against the risk of icing are also to be provided.
(b) Means of ensuring that loads are not transmitted from the engine to the ducting, such as a flexible bellows, *see Vol 2, Pt 7, Ch 1, 14 Expansion pieces*.
(c) A debris screen that is easily accessible for cleaning located close to the engine.

8.6.5 The design of induction air systems is to provide a nominal constant air speed that should be as low as reasonably practicable to minimise pressure losses. The inlet pressure drop across the system, including filters and silencers, etc. is not to exceed the engine manufacturer's recommendations.

8.6.6 Air induction system intakes are to be designed and installed such that turbulent flow is not induced therein by ship motions.

■ *Section 9*
Control and monitoring of main, auxiliary and emergency engines

9.1 General

9.1.1 The Control and Monitoring systems are to comply with the requirements of *Vol 2, Pt 9 Electrotechnical Systems*. *See Vol 2, Pt 1, Ch 3, 4 Operating conditions* for requirements for operating conditions.

9.1.2 Oil mist detection, engine bearing temperature monitors or alternative methods for crankcase protection are to be provided:

(a) When arrangements are fitted to override the automatic shutdown for excessive reduction of the lubricating oil supply pressure.
(b) For engines of 2,250 kW and above or having cylinders of more than 300 mm bore.

Note 1. For trunk piston engines automatic shutdown of the engine is to occur.

Note 2. For crosshead engines, automatic slow-down is to occur.

Note 3. Where arrangements are made to override the automatic slow-down or shutdown due to high oil mist or bearing temperature, the override is to be independent of other overrides.

Note 4. Where the bearing temperature monitoring method is chosen, all bearings in the crankcase are to be monitored where practicable, e.g. main, crankpin, crosshead.

Note 5. Where engine bearing temperature monitors or alternative methods are provided for the prevention of the build up of oil mist that may lead to a potentially explosive condition within the crankcase, details are to be submitted for consideration. The submission is to demonstrate that the arrangements are equivalent to those provided by oil mist detection, *see Vol 2, Pt 2, Ch 1, 6.8 Oil mist detection 6.8.14*.

9.1.3 All main and auxiliary engines intended for Mobility or Ship Type systems are to be provided with means of indicating the lubricating oil pressure supply to them. Where such engines are of more than 37 kW, audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. Further, these alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

9.2 Main engine governors

9.2.1 An efficient speed governor is to be fitted to each main engine so adjusted that the speed does not exceed that for which the engine is to be certified by more than 15 per cent.

9.2.2 Engines coupled to electrical generators that are the source of power for main electric propulsion are to comply with the requirements for electrical generator engines in respect of governors and overspeed protection devices.

9.3 Auxiliary engine governors

9.3.1 Auxiliary engines intended for driving electrical generators are to be fitted with governors which, with fixed setting, are to control the speed. Unless otherwise required by the electrical system power supply requirements, the governor is to control the engine speed within 10 per cent momentary variation and five per cent permanent variation when the full load is suddenly taken off or, when after running on no load for at least 15 minutes, the load is suddenly applied as follows:

(a) For engines with BMEP less than 8 bar, full load, or
(b) For engines with BMEP greater than 8 bar, 800/BMEP per cent, but not less than one-third, of full load, the full load being attained in not more than two additional equal stages as rapidly as possible.

9.3.2 If an engine cannot achieve the requirements of *Vol 2, Pt 2, Ch 1, 9.3 Auxiliary engine governors 9.3.1* then the actual load step is to be declared and verified through testing to ensure the requirements specified in *Vol 2, Pt 9, Ch 1, 2.1 Quality of power supplies (QPS)* are satisfied.

9.3.3 The no-load stability of governors on electrical generator engines is to be such as to enable satisfactory paralleling to be achieved.

9.3.4 For alternating current installations, the permanent speed variations of the machines intended for parallel operation are to be equal within a tolerance of ±0.5 per cent. Momentary speed variations with load changes in accordance with *Vol 2, Pt 2, Ch 1, 9.3 Auxiliary engine governors 9.3.1* are to return to and remain within one per cent of the final steady state speed. Where there are no stated electrical power supply requirements for a particular installation, this should normally be accomplished within five but in no case more than eight seconds. For quality of power supplies, *see Vol 2, Pt 9, Ch 1, 2.1 Quality of power supplies (QPS)*.

9.3.5 Emergency generator engines are to comply with *Vol 2, Pt 2, Ch 1, 9.3 Auxiliary engine governors 9.3.1* except that the initial load required by *Vol 2, Pt 2, Ch 1, 9.3 Auxiliary engine governors 9.3.1* is to be not less than the total connected emergency load, or if their total consumer load is applied in steps, the following requirements are to be met:

(a) the total load is supplied within 45 seconds from power failure on the main switchboard;
(b) the maximum step load is declared and demonstrated; and
(c) the power distribution system is designed such that the declared maximum step loading is not exceeded.

9.3.6 Compliance of time delays and loading sequence with the requirements of *Vol 2, Pt 2, Ch 1, 9.3 Auxiliary engine governors 9.3.4* is to be demonstrated at ship's trials.

9.4 Overspeed protective devices

9.4.1 Each main engine developing 220 kW or over which can be declutched or which drives a controllable pitch propeller and also each auxiliary engine developing 220 kW and over for driving an electric generator, is to be fitted with an approved overspeed protective device.

9.4.2 The overspeed protective device, including its driving mechanism, is to be independent of the governor required by *Vol 2, Pt 2, Ch 1, 9.4 Overspeed protective devices* or *Vol 2, Pt 2, Ch 1, 9.5 Engine stopping* and is to be so adjusted that the speed does not exceed that for which the engine and its driven machinery are to be classed by more than 20 per cent for main engines and 15 per cent for auxiliary engines.

9.5 Engine stopping

9.5.1 At least two independent means of stopping the engines quickly from the control station under any conditions are to be available.

9.6 Unattended machinery

9.6.1 Where main and auxiliary engines are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by *Vol 2, Pt 2, Ch 1, 9.1 General* as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

9.6.2 Where machinery is arranged to start automatically or from a remote control station, interlocks are to be provided to prevent start-up under conditions which could present a hazard to the machinery.

9.6.3 Where machinery specified in this Section is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

9.6.4 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery are required by *Table 1.9.1 Engines for propulsion purposes: Alarms and slow-downs* and *Table 1.9.2 Engines for propulsion purposes: Automatic shutdowns* and *Table 1.9.3 Auxiliary engines: Alarms and shutdowns*, the sensors and circuits utilised for the second stage alarm and automatic shutdown are to be independent of those required for the first stage alarm.

9.6.5 Means are to be provided to prevent leaks from high pressure fuel oil injection piping for main and auxiliary engines dripping or spraying onto hot surfaces or into machinery air inlets. Such leakage is to be collected and, where practicable, led to a collector tank(s) fitted in a safe position. An alarm is to be provided to indicate that leakage is taking place. These requirements may also be applicable to high pressure hydraulic oil piping depending upon the location.

9.7 Engines for propulsion purposes

9.7.1 Alarms and safeguards are indicated in *Vol 2, Pt 2, Ch 1, 9.7 Engines for propulsion purposes 9.7.2* to *Vol 2, Pt 2, Ch 1, 9.7 Engines for propulsion purposes 9.7.8* and *Table 1.9.1 Engines for propulsion purposes: Alarms and slow-downs* and *Table 1.9.2 Engines for propulsion purposes: Automatic shutdowns*. *See also Vol 2, Pt 2, Ch 1, 9.1 General 9.1.2* and *Vol 2, Pt 2, Ch 1, 9.6 Unattended machinery 9.6.5*.

Table 1.9.1 Engines for propulsion purposes: Alarms and slow-downs

Item	Alarm	Note
Lubricating oil sump level	Low	Engines
Lubricating oil inlet pressure*	1st stage	Engines.
	Low	Slow-down
Lubricating oil inlet temperature*	High	Engines
Lubricating oil filters differential pressure	High	—
Oil mist concentration in crankcase or bearing temperature	High	Automatic slow-down of crosshead engines, *see Vol 2, Pt 2, Ch 1, 9.1 General 9.1.2*. For trunk piston engines, *see Table 1.9.2 Engines for propulsion purposes: Automatic shutdowns*
Cylinder lubricator flow	Low	One sensor per lubricator unit on crosshead engines. Slow-down
Thrust bearing temperature*	High	Slow-down
Common rail servo oil pressure	Low	

Piston coolant inlet pressure	Low	If a separate system. Slow-down
Piston coolant outlet temperature*	High	Per cylinder (if a separate system). Slow-down
Piston coolant outlet flow*	Low	Per cylinder (if a separate system). Slow-down
Cylinder coolant inlet pressure or flow*	Low	Slow-down (automatic on trunk piston engines)
Cylinder coolant outlet temperature*	1st stage high	Per cylinder (if a separate system) Slow-down (automatic on trunk piston)
Engine cooling water system – oil content	High	Where engine cooling water used in heat exchangers
Sea-water cooling pressure	Low	—
Fuel valve coolant pressure	Low	If a separate system
Fuel valve coolant temperature	High	If a separate system
Fuel oil pressure from booster pump	Low	—
Fuel oil temperature or viscosity*	High and Low	Heavy oil only
Common rail fuel oil pressure	Low	
Fuel oil high pressure piping*	Leakage	*See Vol 2, Pt 2, Ch 1, 9.6 Unattended machinery*
Charge air cooler outlet temperature	High and Low	Trunk piston engines
Scavenge air temperature (fire)	High	Per cylinder, (2 stroke engines). Slow-down
Scavenge air receiver water level	High	—
Exhaust gas temperature*	High	Per cylinder. Slow-down (automatic on trunk piston engines), *see* Note 5
Exhaust gas temperature deviation from average*	High	Per cylinder, for engine power >500 kW/cylinder. *See* Note 5
Turbocharger exhaust gas inlet temperature	High	Each turbocharger, *see* Note 9
Turbocharger exhaust gas outlet temperature*	High	Each turbocharger
Turbocharger lubricating oil inlet pressure	Low	*See* Note 10
Turbocharger lubricating oil outlet temperature	High	Each bearing, if system not integral with turbocharger. *See* Notes 8 and 10
Starting air pressure*	Low	Before engine manoeuvring valve
Control air pressure	Low	—
Direction of rotation	Wrong way	Reversible engines, *see also Vol 2, Pt 2, Ch 1, 9.7 Engines for propulsion purposes 9.7.8*
Automatic start of engine	Failure	*See Vol 2, Pt 2, Ch 1, 9.7 Engines for propulsion purposes 9.7.8*
Electrical starting battery charge level*	Low	Electric start engines, *see also Vol 2, Pt 2, Ch 1, 7.2 Electrical starting arrangements 7.2.5*
Feed water or water/thermal fluid forced circulation flow (if fitted)	Low	*See Vol 2, Pt 7, Ch 3, 6.2 Feed and circulation pumps 6.2.6* and Note 6
Uptake temperature	High	To monitor for soot fires. *See* Notes 6 and 7
Note 1. Where 'per cylinder' appears in this Table, suitable alarms may be situated on manifold outlets for trunk piston engines.		
Note 2. For engines and gearing of 1500 kW or less only the items marked * are required.		

Note 3. Common sensors are acceptable for alarms and slow-down functions.

Note 4. Except where stated otherwise in the Table, slow-down may be effected by either manual or automatic means, by reduction of speed or power as appropriate.

Note 5. For trunk piston engine powers <500 kW/cylinder, but total power >500 kW, a common sensor for exhaust gas manifold temperature may be fitted.

Note 6. Alarm only required when an exhaust gas economiser/boiler/thermal oil heater is fitted.

Note 7. Alternatively, details (including location) of an appropriate fire detection system are to be submitted for consideration.

Note 8. Where the outlet temperature for each bearing cannot be measured due to the design, details of alternative proposals in accordance with the turbocharger manufacturer's instructions may be submitted for consideration.

Note 9. Alarm and indication of the exhaust gas temperature at turbocharger inlet may be waived if alarm and indication for individual exhaust gas temperature is provided for each cylinder and the alarm level is set to a value specified by the turbocharger manufacturer.

Note 10. Separate sensors are to be provided if the lubrication oil system of the turbocharger is not integrated with the lubrication oil system of the engine or if it is separated by a throttle or pressure reduction valve from the engine lubrication oil system. Where the turbocharger is provided with a self-contained lubricating oil system integrated with the turbocharger, lubricating oil inlet pressure need not be monitored.

Table 1.9.2 Engines for propulsion purposes: Automatic shutdowns

Item	Alarm	Note
Lubricant oil inlet pressure	2nd stage low	Automatic shutdown of engines, *see Vol 2, Pt 2, Ch 1, 9.6 Unattended machinery 9.6.4*
Oil mist concentration in crankcase or bearing temperature	High	Automatic shutdown of trunk piston, *see Vol 2, Pt 2, Ch 1, 9.1 General 9.1.2*
Cylinder coolant outlet temperature	2nd stage high	Automatic shutdown of trunk piston, *see Vol 2, Pt 2, Ch 1, 9.6 Unattended machinery 9.6.4*
Overspeed	High	Automatic shutdown of engine, *see also Vol 2, Pt 2, Ch 1, 9.4 Overspeed protective devices*. Details of alternative proposals in accordance with the manufacturer's instructions may be submitted for consideration

9.7.2 Alarms are to operate for the fault conditions shown in *Table 1.9.1 Engines for propulsion purposes: Alarms and slow-downs*. Where applicable, indication is to be given at the relevant control stations that the speed or power of the main propulsion engine(s) is to be manually reduced or has been reduced automatically.

9.7.3 Alarms are to operate, and automatic shutdown of machinery is to occur for the fault conditions shown in *Table 1.9.2 Engines for propulsion purposes: Automatic shutdowns*.

9.7.4 The following engine services are to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the propulsion engine(s):

(a) Lubricating oil supply.
(b) Piston coolant supply, where applicable.
(c) Cylinder coolant supply, where applicable.
(d) Fuel valve coolant supply, where applicable.
(e) Fuel oil supply, where fuel oil grades require heating or cooling only, *see also Vol 2, Pt 2, Ch 1, 9.7 Engines for propulsion purposes 9.7.5*.

9.7.5 The oil fuel supply may be fitted with an automatic control for viscosity instead of the temperature control required by *Vol 2, Pt 2, Ch 1, 9.7 Engines for propulsion purposes 9.7.4*.

9.7.6 Indication of the starting air pressure is to be provided at each control station from which it is possible to start the main propulsion engine(s).

9.7.7 The number of automatic consecutive attempts which fail to produce a start are to be limited to three attempts. For reversible engines which are started and stopped for manoeuvring purposes, means are to be provided to maintain sufficient starting air in the air receivers. For electric starting, *see Vol 2, Pt 2, Ch 1, 7.2 Electrical starting arrangements*.

9.7.8 Prolonged running in a restricted speed range is to be prevented automatically or, alternatively, an indication of restricted speed ranges is to be provided at each control station.

9.8 Auxiliary and other engines

9.8.1 Alarms and safeguards are indicated in *Table 1.9.3 Auxiliary engines: Alarms and shutdowns See also Vol 2, Pt 2, Ch 1, 9.1 General 9.1.2* and *Vol 2, Pt 2, Ch 1, 9.6 Unattended machinery 9.6.5*.

9.8.2 For engines operating on heavy fuel oil, automatic temperature of viscosity controls are to be provided.

Table 1.9.3 Auxiliary engines: Alarms and shutdowns

Item	Alarm	Note
Lubricating oil inlet temperature	High	—
Lubricating oil inlet pressure	1st stage low	—
Lubricating oil inlet pressure	2nd stage low	Automatic shutdown of engine, *see Vol 2, Pt 2, Ch 1, 9.6 Unattended machinery 9.6.4*
Oil mist concentration in crankcase or bearing temperature	High	Automatic shutdown of engine, *see Vol 2, Pt 2, Ch 1, 9.1 General 9.1.2*
Fuel oil high pressure piping	Leakage	*See Vol 2, Pt 2, Ch 1, 9.6 Unattended machinery 9.6.5*
Coolant outlet temperature (for engines >220 kW)	1st stage high	—
Coolant outlet temperature (for engines >220 kW)	2nd stage high	Automatic shutdown of engine, *see Vol 2, Pt 2, Ch 1, 9.6 Unattended machinery 9.6.5*
Coolant pressure or flow	Low	—
Fuel oil temperature or viscosity	High and Low	Heavy oil only
Overspeed	High	Automatic shutdown of engine, *see also Vol 2, Pt 2, Ch 1, 9.4 Overspeed protective devices*. Details of alternative proposals in accordance with the manufacturer's instructions may be submitted for consideration.
Common rail servo oil pressure	Low	
Common rail fuel oil pressure	Low	
Starting air pressure	Low	—
Electrical starting battery charge level	Low	Electric start engines, *see also Vol 2, Pt 2, Ch 1, 7.2 Electrical starting arrangements 7.2.5*
Exhaust gas temperature (for engines >500 kW/ cylinder)	High	Per cylinder.
Feed water or water/thermal fluid forced circulation flow (if fitted)	Low	*See Vol 2, Pt 7, Ch 3, 6.2 Feed and circulation pumps 6.2.6* and Note 2
Turbocharger lubricating oil outlet temperature	High	Each bearing, *see* Note 5

Turbocharger lubrication oil inlet pressure	Low	*See* Note 6
Uptake temperature	High	To monitor for soot fires. *See* Notes 2 and 3

Note 1. The tailoring document or System Design Description may specify additional requirements of the Naval Administration.

Note 2. Alarm only required when an exhaust gas economiser/boiler/thermal oil heater is fitted.

Note 3. Alternatively, details (including location) of an appropriate fire detection system are to be submitted for consideration.

Note 4. For emergency engines, including engines used for the emergency source of electrical power required by SOLAS, see *Vol 2, Pt 7, Ch 3, 12 Air compressors and air starting arrangements*.

Note 5. Unless provided with a self-contained lubricating oil system integrated with the turbocharger.

Note 6. Where outlet temperature from each bearing cannot be monitored due to the engine/turbocharger design, alternative arrangements may be accepted. Continuous monitoring of inlet pressure and inlet temperature in combination with specific intervals for bearing inspection in accordance with the turbocharger manufacturer's instructions may be accepted as an alternative.

9.9 Alarms and safeguards for emergency engines

9.9.1 These requirements apply to emergency engines required to be immediately available in an emergency and capable of being controlled remotely or automatically.

9.9.2 Alarms and safeguards are indicated in *Table 1.9.4 Alarms and safeguards for emergency engines*. *See also Vol 2, Pt 2, Ch 1, 9.1 General 9.1.2* and *Vol 2, Pt 2, Ch 1, 9.6 Unattended machinery 9.6.5*.

Table 1.9.4 Alarms and safeguards for emergency engines

Item	Alarm	Alarm	Note
Emergency Engine	≥ 220 kW	<220 kW	-
Fuel oil leakage from pressure pipes	Leakage	Leakage	*See Vol 2, Pt 2, Ch 1, 9.6 Unattended machinery 9.6.5*
Lubricating oil temperature	High	-	-
Lubricating oil pressure	Low	Low	-
Oil mist concentration in crankcase	High	-	*See* Note 1
Coolant pressure or flow	Low	-	-
Coolant Temperature (can be air)	High	High	-
Overspeed	High	-	Automatic shutdown

Note 1. For engines having a power of more than 2250 kW or a cylinder bore of more than 300 mm.

9.9.3 The safety and alarm systems are to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the system and its associated machinery, but also the complete installation, as well as the ship.

9.9.4 Regardless of the engine output, if shutdowns additional to those specified in *Table 1.9.4 Alarms and safeguards for emergency engines* are provided except for the overspeed shutdown, they are to be automatically overridden when the engine is in automatic or remote control mode during navigation.

9.9.5 Grouped alarms of at least those items listed in *Table 1.9.4 Alarms and safeguards for emergency engines* are to be arranged on the bridge.

9.9.6 In addition to the fuel oil control from outside the space, a readily accessible local means of engine shutdown is to be provided.

9.9.7 Local indications of at least those items listed in *Table 1.9.4 Alarms and safeguards for emergency engines* are to be provided within the same space as the engines and are to remain operational in the event of failure of the alarm and safety systems.

■ *Section 10*
Factory Acceptance Test and Shipboard Trials of Internal Combustion Engines

10.1 Safety

10.1.1 Before any test run is carried out, all relevant equipment for the safety of attending personnel is to be made available by the manufacturer/ shipyard and is to be operational. This is to include crankcase explosive conditions protection, overspeed protection and any other shutdown function.

10.1.2 The overspeed protective device is to be set to a value which is not higher than the overspeed value that was demonstrated during the type test for that engine. This set point is to be verified by the Surveyor.

10.2 General

10.2.1 Engines which are to be subjected to trials on the test bed at the manufacturer's works and under attendance by the Surveyor(s) are to be tested in accordance with the scope of works trials specified in *Vol 2, Pt 2, Ch 1, 10.3 Works trials (factory acceptance test)*. The scope of the trials is to be agreed between the LR Surveyor and the manufacturer prior to testing. At the discretion of the Surveyor, the scope of the trials may be extended depending on the engine application.

10.2.2 Where multiple engines of the same design are manufactured, a quality assurance approach to approval may be applied if the manufacturer meets the requirements of and is registered on the Quality Assurance Scheme for Machinery (QAM), *see Vol 2, Pt 2, Ch 1, 6 Safety arrangements on engines*.

10.2.3 Before any official testing the engines are to be run in as prescribed by the engine manufacturer.

10.2.4 Adequate test bed facilities for loads as required in *Table 1.10.1 Scope of works trials for engines* are to be provided. All fluids used for testing purposes such as fuel, lubrication oil and cooling water are to be suitable for the purpose intended, e.g. they are to be clean and if necessary, pre-heated to achieve the recommended operating temperature. This applies to all fluids used temporarily or repeatedly for testing purposes only.

10.2.5 Survey of the engine is to include:

(a) Jacketing of high-pressure fuel oil lines including the system used for the detection of leakage.
(b) Screening of pipe connections in piping containing flammable liquids.
(c) Insulation of hot surfaces by taking random temperature readings that are to be compared with corresponding readings obtained during the type test. This is to be done while running at the maximum approved rating for the actual application. Use of contact thermometers may be accepted at the discretion of the attending Surveyor. If the insulation is modified subsequently to the Type Approval Test, LR may request more enhanced temperature measurements as required by the LR's Type Approval Test Specification No. 4, Chapter 2, 1.3.10 (Fire Protection Measures).

These surveys are normally to be made during the works trials by the manufacturer and the attending Surveyor, but at the discretion of LR parts of these surveys may be postponed to the shipboard testing.

10.2.6 Where the type test was not carried out on the complete engine, as described in *Vol 2, Pt 2, Ch 1, 1.1 Application 1.1.5*, integration tests are to be conducted as part of the works or shipboard trials to confirm satisfactory operation of the complete engine. This includes satisfactory functioning on all fuel types on which the engine is to operate. *See also Vol 2, Pt 2, Ch 1, 10.4 Shipboard trials 10.4.7*.

10.3 Works trials (factory acceptance test)

10.3.1 The purpose of the works trials is to verify design parameters such as power, adherence to approved limits (e.g. maximum pressure) and functionality, and to establish reference values or base lines for later reference in the operational phase.

10.3.2 For each load point the parameters to be recorded include: Power and speed; Fuel index (or equivalent reading); Maximum combustion pressures; Exhaust gas temperature before turbine and from each cylinder (or from manifold, *see* Note 5 in Table 1.9.1 Engines for propulsion purposes: Alarms and slow-downs); Charge air temperature and pressure.

10.3.3 For all stages of the works trials the pertaining operation values are to be measured and recorded by the engine manufacturer. All results are to be compiled in an acceptance protocol to be issued by the engine manufacturer. Where the engine designer requires through life monitoring of crankshaft deflections, such measurements are also to be taken before and after works acceptance trials in accordance with the engine designer's requirements.

10.3.4 In each case given in *Table 1.10.1 Scope of works trials for engines* Scope of works trials for engines, all measurements conducted at the various load points are to be carried out at steady operating conditions. The readings for MCR, i.e. 100 per cent power (rated maximum continuous power at corresponding rpm) are to be taken twice at an interval of at least 30 minutes. For all load points provision should be made for time needed by the Surveyor to carry out visual inspections.

10.3.5 Calibration records for the instrumentation are to be presented to the attending Surveyor upon request.

Table 1.10.1 Scope of works trials for engines

Main engines driving propellers and waterjets		
Trial condition	Duration	Note
100% power (rated power) at rated engine speed, R	≥60 minutes	After having reached steady conditions
110% power at engine speed corresponding to 1032*R	30–45 minutes	After having reached steady conditions (*see* Note 1)
90% (or maximum continuous power), 75%, 50% and 25%	—	Powers in accordance with the nominal propeller curve
Starting and reversing manoeuvres	—	—
Testing of governor and independent overspeed protective device	—	*See Vol 2, Pt 2, Ch 1, 7.2 Electrical starting arrangements*
Shutdown device	—	*See Vol 2, Pt 2, Ch 1, 7.4 Engine control, alarm, monitoring and safety system power supplies*
Engines driving generators		
Trial condition	Duration	Note
100% power (rated power) at rated engine speed, R	≥50 minutes	After having reached steady conditions (*see* Note 2)
110% power	30 minutes	After having reached steady conditions (*see* Notes 2 and 3)
75%, 50% and 25% power and idle run	—	(*see* Note 2)
Start-up tests	—	—
Testing of governor and independent overspeed protective device	—	*See Vol 2, Pt 2, Ch 1, 7.3 Starting of the emergency source of power*
Shutdown device	—	*See Vol 2, Pt 2, Ch 1, 7.4 Engine control, alarm, monitoring and safety system power supplies*
Note 1. After running on the test bed, the fuel delivery system of main engines is normally to be so adjusted that overload power cannot be given in service. Note 2. The test is to be performed at rated speed with a constant governor setting. Note 3. After running on the test bed, the fuel delivery system of engines driving generators must be adjusted such that overload (110%) power can be given in service after installation on board, so that the governing characteristics including the activation of generator protective devices can be fulfilled at all times.		

10.3.6 Alternatives to the detailed tests may be agreed between the manufacturer and LR when the overall scope of tests is found to be equivalent. The scope of the trials may be expanded depending on the engine application, service experience, or other relevant reasons.

10.3.7 For electronically controlled engines:

(a) integration tests in accordance with *Vol 2, Pt 2, Ch 1, 2.2 Submission requirements*; and

(b) verification of engine configuration, *see Vol 2, Pt 2, Ch 1, 13.3 Control engineering systems 13.3.2*, and that the approved software quality plans, including the software configuration management process, are to be applied.

10.3.8 Checks of components to be presented for inspection after the works trials are left to the discretion of the Surveyor.

10.3.9 The Surveyor may require that after the trials the fuel delivery system is restricted so as to limit the engines to run at not more than 100 per cent power. The setting of the restriction is to be made as applicable to the intended fuel. Any restriction settings, and other changes to the engine's fuel injection equipment required for operation on special fuels, are to be recorded and included by the engine manufacturer.

10.3.10 For the duration of the acceptance test, no interventions or adjustments will be made to the machinery under test.

10.3.11 The testing of exhaust gas emissions is to comply with *MARPOL - International Convention for the Prevention of Pollution from Ships* as applicable.

10.4 Shipboard trials

10.4.1 The purpose of the shipboard testing is to verify compatibility with power transmission and driven machinery in the system, safety, control and auxiliary systems necessary for the engine and integration of engine/ shipboard control systems, as well as other items that had not been dealt with in the FAT (Factory Acceptance Testing).

10.4.2 After installation on board, engines are to undergo shipboard trials as specified in *Table 1.10.2 Scope of shipboard trials for engines*. The scope of the trials may be expanded depending on the engine application, service experience or other relevant reasons, and is to be agreed between the LR Surveyor and the Shipyard prior to testing.

Table 1.10.2 Scope of shipboard trials for engines

Main engines driving fixed-pitch propellers (*see* Notes 1 and 2)		
Trial condition	Duration	Note
At rated engine speed, R	≥ 4 hours	–
At engine speed corresponding to normal continuous power	≥ 2 hours	–
At engine speed corresponding to 1,032*R	30 minutes	Where the engine adjustment permits, *see Vol 2, Pt 2, Ch 1, 11.1 General 11.1.7*
At minimum on-load speed	–	–
Starting and reversing manoeuvres	–	*See Vol 2, Pt 2, Ch 1, 7 Starting arrangements* and *Vol 2, Pt 7, Ch 3, 12 Air compressors and air starting arrangements*
In reverse direction of propeller rotation during the dock or sea trials at a minimum engine speed of 0,7*R	10 minutes	–
Control, monitoring, alarms and safety systems	–	Operation to be demonstrated
Where imposed, test to ensure engine can pass safely through barred speed range	–	–
Single engine driving a generator for propulsion only		
Trial condition	Duration	Note
100% power (rated propulsion power), *see Vol 2, Pt 2, Ch 1, 10.4 Shipboard trials 10.4.3*	≥ 4 hours	(*see* Notes 3 and 4)
At normal continuous propulsion power	≥ 2 hours	(*see* Notes 3 and 4)
110% power (rated propulsion power)	30 minutes	–
In reverse direction of propeller rotation at a minimum speed of 70% of the nominal propeller speed	10 minutes	(*see* Notes 3 and 4)
Starting manoeuvres	–	–

Control, monitoring, alarm and safety systems	–	Operation to be demonstrated
Note 1. For main propulsion engines driving controllable pitch propellers, waterjets or reversing gears, the tests for main engines driving fixed-pitch propellers apply as appropriate. **Note** 2. Controllable pitch propellers are to be tested with various propeller pitches. **Note** 3. The tests are to be performed at rated speed with a constant governor setting. **Note** 4. Tests are to be based on the rated electrical powers of the electric propulsion motors.		

10.4.3 Engines driving generators or other auxiliaries for Mobility or Ship Type systems are to be subjected to an operational test for at least 4 hours. During the test, the set concerned is required to operate at its rated power for an extended period. It is to be demonstrated that the engine is capable of supplying 100 per cent of its rated power, and in the case of shipboard generating sets account shall be taken of the times needed to actuate the generator's overload protection system.

10.4.4 Trials are to include demonstration of engine control, monitoring, alarm and safety system operation to confirm that they have been provided, installed and configured as intended and in accordance with the relevant requirements for main, auxiliary or emergency engines except items already verified during the works trials.

10.4.5 For electronically controlled engines:

(a) shipboard tests in accordance with *Vol 2, Pt 2, Ch 1, 2.2 Submission requirements*; and
(b) verification of engine configuration, *see Vol 2, Pt 2, Ch 1, 13.3 Control engineering systems 13.3.2*, and that the approved software quality plans, including the software configuration management process, are to be applied.

10.4.6 The suitability of an engine to burn residual or other special fuels is to be demonstrated where the machinery installation is arranged to burn such fuels in service. *See also Vol 2, Pt 9, Ch 11, 1.5 Unattended machinery space operation - UMS notation*.

10.4.7 For both manual and automatic engine control systems, acceleration and deceleration through any barred speed range, is to be demonstrated. The transit times are to be equal or less than the times stated in the approved documentation and are to be recorded. This also applies when passing through the barred speed range in reverse rotational direction, especially during the stopping test. The ship's draft and speed during all these demonstrations are to be recorded. Where a controllable pitch propeller is fitted, the pitch is also to be recorded.

10.4.8 The engine is to be checked for stable running (steady fuel index) at both upper and lower borders of the barred speed range. Steady fuel index means an oscillation range less than five per cent of the effective stroke (idle to full index).

■ *Section 11* **Turbochargers**

11.1 General

11.1.1 Turbochargers are to be approved, either separately or as a part of an engine. The requirements are written for exhaust gas driven turbochargers, but apply in principle also for engine driven chargers.

11.1.2 Some requirements are reduced for turbochargers manufactured on the basis of mass production methods. Mass produced turbochargers are defined as those which are produced under the following criteria:

(a) In quantity under strict quality control of material and parts, according to a quality assurance scheme acceptable to LR.
(b) By the use of jigs and automatic machine tools designed to machine parts to specified tolerances for interchangeability, and which are verified on a regular inspection basis.
(c) By assembly with parts taken from stock and requiring little or no fitting.
(d) With bench tests carried out on individual assembled turbochargers according to a specified programme.
(e) With appraisal by final examination of turbochargers selected at random after workshop testing.

11.1.3 Plans and particulars are to be submitted as required by *Vol 2, Pt 2, Ch 1, 2.2 Submission requirements 2.2.4*.

11.1.4 Alarms and slowdowns for turbochargers are required as listed in *Table 1.9.1 Engines for propulsion purposes: Alarms and slow-downs*, *Table 1.9.2 Engines for propulsion purposes: Automatic shutdowns* and *Table 1.9.3 Auxiliary engines: Alarms and shutdowns*.

11.1.5 Turbochargers are to be designed for the operating conditions defined in *Vol 2, Pt 1, Ch 3, 4 Operating conditions*. The component lifetime and the alarm level for speed are to be based on 45°C air inlet temperature.

11.1.6 A Type test, *see Vol 2, Pt 2, Ch 1, 12.2 Turbochargers*, is to be carried out on a standard unit taken from the assembly line and is to be witnessed by the Surveyor.

11.1.7 LR reserves the right to limit the duration of validity of approval of a mass produced turbocharger. LR is to be informed, without delay, of any change in the design of the turbocharger, in the manufacturing or control processes, in the selection of materials or in the list of subcontractors for main parts.

11.2 Dynamic balancing

11.2.1 All rotors are to be dynamically balanced on final assembly to the Surveyor's satisfaction.

11.3 Overspeed tests

11.3.1 All fully bladed rotor sections and impeller/inducer wheels are to be overspeed tested for three minutes at either 20 per cent above the maximum permissible speed at room temperature or 10 per cent above the maximum permissible speed at the normal working temperature. The overspeed test may be waived for forged wheels that are individually controlled by an approved non-destructive method; this test will not be waived for wheels of the unit to be type tested.

11.4 Mechanical running tests

11.4.1 Turbochargers are to be given a mechanical running test of 20 minutes duration at the maximum permissible speed.

11.4.2 Upon application, with details of a historical audit covering previous testing of turbochargers manufactured under an approved quality assurance scheme, consideration will be given to confining the test outlined in *Vol 2, Pt 2, Ch 1, 11.3 Overspeed tests 11.3.1* to a representative sample of turbochargers.

11.5 Containment

11.5.1 In the event of any rotor burst, the turbocharger casing is to fully contain all debris and no part may penetrate the casing of the turbocharger or escape through the air intake.

11.5.2 Containment is to be demonstrated by testing which is to be fully documented. For approval of a generic range of turbochargers, subject to satisfactory performance, only the largest unit is required to be tested. In any case, it must be demonstrated (e.g. by calculation) that the selected test unit is representative for the whole generic range.

11.5.3 The minimum test speeds for rotor burst testing is to be the same as those required for the overspeed test specified in *Vol 2, Pt 2, Ch 1, 11.3 Overspeed tests 11.3.1*.

11.5.4 Containment tests are to be performed at working temperature.

11.5.5 Calculations using a simulation model and numerical analysis to demonstrate the required containment may be accepted in lieu of the practical containment test, provided that:

(a) The numerical simulation model has been validated and its suitability/accuracy has been proven by direct comparison between calculation results and the practical containment test for a reference application (reference containment test). This test is to be performed at least once by the manufacturer for acceptance of the numerical simulation method in lieu of tests.
(b) The corresponding numerical simulation for the containment is performed for the same speeds as specified for the containment test.
(c) Material properties for high-speed deformations are to be applied in the numeric simulation. The correlation between normal properties and the properties at the pertinent deformation speed are to be substantiated.
(d) The design of the turbocharger regarding geometry and kinematics is similar to the turbocharger that was used for the reference containment test. In general, totally new designs will call for a new reference containment test.

11.6 Disk-shaft shrinkage fit

11.6.1 For turbochargers where the disc is connected to the shaft with an interference fit, calculations are to substantiate safe torque transmission during all relevant operating conditions such as maximum speed, maximum torque and maximum temperature gradient combined with minimum shrinkage amount.

11.7 Works testing and inspection

11.7.1 LR Surveyors are to be provided with free access to the manufacturer's workshop to inspect at random the quality control measures and to witness the tests required by *Vol 2, Pt 2, Ch 1, 11.7 Works testing and inspection 11.7.3* to *Vol 2, Pt 2, Ch 1, 11.7 Works testing and inspection 11.7.7* as deemed necessary, and to have free access to all control records and subcontractors' certificates.

11.7.2 Each individual unit is to be tested in accordance with, *Vol 2, Pt 2, Ch 1, 11.7 Works testing and inspection 11.7.4* to *Vol 2, Pt 2, Ch 1, 11.7 Works testing and inspection 11.7.7*.

11.7.3 Rotating parts of the turbocharger blower are to be marked for easy identification with the corresponding certificate. Component identification is to be in accordance with the Rules for Materials.

11.7.4 Material tests of the rotating parts are to be in accordance with the requirements of the Rules for Materials as applicable.

11.7.5 Pressure tests are to be carried out in accordance with *Table 1.3.1 Test and certification requirements for engine components*. Special consideration will be given where design or testing features may require modification of the test requirements.

11.7.6 Dynamic balancing and overspeed tests are to be carried out, *see Vol 2, Pt 2, Ch 1, 11.2 Dynamic balancing* and *Vol 2, Pt 2, Ch 1, 11.3 Overspeed tests*.

11.7.7 A mechanical running, is to be carried out, *see Vol 2, Pt 2, Ch 1, 11.4 Mechanical running tests*. The duration of the running test may be reduced to 10 minutes provided that the manufacturer is able to verify the distribution of defects established during the running tests on the basis of a sufficient number of tested turbochargers. For manufacturers who have facilities in their Works for testing the turbochargers on an engine for which the turbochargers are intended, the bench test may be replaced by a test run of 20 minutes at overload (110% of the rated output) on this engine.

11.8 Certification

11.8.1 The manufacturer is to adhere to a quality system designed to ensure that the designer's specifications are met, and that manufacturing is in accordance with the approved drawings.

11.8.2 Turbochargers are to be delivered with:

(a) For turbochargers manufactured using mass production methods as defined in *Vol 2, Pt 2, Ch 1, 11.1 General 11.1.2*, a manufacturer's certificate that at a minimum cites the applicable type approval, including production assessment.
(b) For all other turbochargers, an LR certificate that at a minimum cites the applicable type approval and the LR Quality Scheme when applicable.

11.8.3 Where the manufacturer is approved under the LR Quality Assurance for Machinery Scheme (QAM), the audits will include specific focus on:

(a) Chemical composition of material for the rotating parts.
(b) Mechanical properties of the material of a representative specimen for the rotating parts and the casing.
(c) UT and crack detection of rotating parts.
(d) Dimensional inspection of rotating parts.
(e) Rotor dynamic balancing.
(f) Hydraulic testing of cooling spaces in accordance with *Table 1.2.1 Plans and particulars to be submitted*.
(g) Overspeed test of all compressor disks as per *Vol 2, Pt 2, Ch 1, 11.3 Overspeed tests 11.3.1*.

■ *Section 12* Type Testing – General

12.1 Engines

12.1.1 New engine types or developments of existing types are to be subjected to an agreed programme of type testing to complement the design appraisal and review of documentation. The programme will need to include short term high power operation where applicable.

12.1.2 Requirements for type testing of engines are contained within the Lloyd's Register Type Approval System, Test Specification No. 4 – *Type Testing of Reciprocating Internal Combustion Engines and Associated Ancillary Equipment*. In all cases the type test specification is to be agreed with LR.

12.1.3 Type testing specifications for other auxiliary systems are to be submitted for approval if they are to be tested separately from the engine.

12.1.4 Wherever practical, type tests are to be conducted with the engine control systems operational in the approved configuration, *see Vol 2, Pt 2, Ch 1, 2.1 Approval process* and *Vol 2, Pt 2, Ch 1, 13.3 Control engineering systems 13.3.2*. Configuration management documents that satisfy the requirements of ISO 10007 or an equivalent national or international standard, are to be reviewed at testing for validity and referenced in the type test report.

12.1.5 In addition to type testing against the requirements of Test Specification No. 4, engines may also be submitted for approval against recognised International or National Standards. Where this additional testing and appraisal is carried out satisfactorily, it will be stated on the Type Approval Certificate.

12.2 Turbochargers

12.2.1 Requirements for type testing of turbochargers are contained within the Lloyd's Register Type Approval System, *Test Specification No. 4 – Type Testing of Reciprocating Internal Combustion Engines and Associated Ancillary Equipment*. In all cases the type test specification is to be agreed with LR.

12.3 Crankcase explosion relief valves

12.3.1 Requirements for type testing of crankcase explosion relief valves are contained within the Lloyd's Register Type Approval System, *Type Testing of Test Specification No. 4 – Reciprocating Internal Combustion Engines and Associated Ancillary Equipment.* In all cases the type test specification is to be agreed with LR.

12.3.2 The test specification is only applicable to explosion relief valves fitted with flame arresters. Where internal oil wetting of a flame arrester is a design feature of an explosion relief valve, alternative testing arrangements that demonstrate compliance with these requirements may be proposed by the manufacturer. The alternative testing arrangements are to be submitted to LR for appraisal.

12.4 Crankcase oil mist detection system

12.4.1 Requirements for type testing of crankcase oil mist detection systems are contained within the Lloyd's Register Type Approval System, *Type Testing of Test Specification No. 4 – Reciprocating Internal Combustion Engines and Associated Ancillary Equipment*. In all cases the type test specification is to be agreed with LR.

12.4.2 This test specification is also applicable to oil mist detection systems intended for gear cases.

12.4.3 Acceptance of crankcase oil mist detection equipment is at the discretion of LR based on the appraisal of plans and particulars and the test house report of the results of type testing. *See Vol 2, Pt 2, Ch 1, 2.2 Submission requirements 2.2.5*.

■ *Section 13*
Electronically controlled engines

13.1 Scope

13.1.1 The requirements of this Section are applicable to engines for propulsion, auxiliary or emergency, *see Vol 2, Pt 2, Ch 1, 13.5 Emergency engines*, power purposes with programmable electronic systems implemented. The requirements of this Section also apply to programmable electronic systems used to control other functions (e.g. starting and control air, cylinder lubrication, etc.) where essential for the operation of the engine.

13.1.2 These engines may be of the crosshead or trunk-piston type. They generally have no direct camshaft driven fuel systems, but have common rail fuel/hydraulic arrangements and may have hydraulic actuating systems for the functioning of the exhaust systems.

13.1.3 The operation of these engines relies on the effective monitoring of a number of parameters such as crank angle, engine speed, temperatures and pressures using programmable electronic systems to provide the services essential for the operation of the engine such as fuel injection, air inlet, exhaust and speed control.

13.1.4 Details of proposals to deviate from the requirements of this Section are to be submitted and will be considered on the basis of a technical justification produced by the engine packager or system integrator.

13.1.5 Each engine is to be configured for the specified performance and is to satisfy the relevant requirements for propulsion, auxiliary or emergency engines.

13.1.6 During the life of the engine details of any proposed changes to control, alarm, monitoring or safety systems which may affect safety and the reliable operation of the engine are to be submitted to LR for approval.

13.2 Risk Assessment (RA)

13.2.1 A Risk Assessment (RA) is to be carried out in accordance with the requirements of *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*, and with the applicable requirements of this sub-Section appropriate to the engine application. The analysis is to be a risk-based consideration of engine operation and ship and personnel safety, and is to demonstrate adequate risk mitigation through fault tolerance and/or reliability in accordance with the specified criteria in *Vol 2, Pt 2, Ch 1, 13.2 Risk Assessment (RA) 13.2.2*, relevant to the engine application.

13.2.2 For ships with a single main propulsion engine, a RA of system reliability, in accordance with *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*, is to be carried out and is to demonstrate that an electronic control system failure:

(a) will not result in the loss of the ability to provide the services essential for the operation of the engine, *see Vol 2, Pt 9, Ch 7, 4.5 Control systems, general requirements 4.5.7* and *Vol 2, Pt 9, Ch 8, 5.4 Additional requirements for Mobility category and safety critical systems 5.4.2*;
(b) will not affect the normal operation of the services essential for the operation of the engine other than those services dependent upon the failed part, *see Vol 2, Pt 9, Ch 8, 5.5 Additional requirements for integrated systems 5.5.4* and *Vol 2, Pt 9, Ch 8, 5.5 Additional requirements for integrated systems 5.5.5*; and
(c) will not leave either the engine, or any equipment or machinery associated with the engine, or the ship in an unsafe condition, *see Vol 2, Pt 9, Ch 7, 4.3 Alarm systems, general requirements 4.3.15*, *Vol 2, Pt 9, Ch 7, 4.4 Safety systems, general requirements 4.4.5*, *Vol 2, Pt 9, Ch 7, 4.5 Control systems, general requirements 4.5.4*, *Vol 2, Pt 9, Ch 8, 5.1 General requirements 5.1.3*, *Vol 2, Pt 9, Ch 8, 5.1 General requirements 5.1.4* and *Vol 2, Pt 9, Ch 8, 5.5 Additional requirements for integrated systems 5.5.5*.

13.2.3 A RA is to be carried out for:

(a) main engines on ships with multiple main engines or other means of providing propulsion power; and/or
(b) auxiliary engines intended to drive electric generators forming the ship's main source of electrical power or otherwise providing power for essential services.

The RA is to demonstrate that adequate hazard mitigation has been incorporated in electronically controlled engine systems or the overall ship installation, with respect to personnel safety and providing propulsion power and/or power for essential services for the safety of the ship. Arrangements satisfying the criteria of *Vol 2, Pt 2, Ch 1, 13.2 Risk Assessment (RA) 13.2.2* will also be acceptable.

13.2.4 For engines for emergency power purposes, a RA is to be carried out to demonstrate that the design incorporates adequate hazard mitigation, such that the likelihood of an electronic engine system failure resulting in the loss of the ability to provide emergency power has been reduced to a level considered acceptable by LR, and that means are provided to detect failures and permit personnel to restore engine availability to operate on demand. Failures which would result in engine failure and/or damage or loss of availability are to be identified and the report is to include documentation of:

(a) component reliability evidence;
(b) failure detection and alarms; and
(c) failure response required to restore engine availability and maintain personnel safety.

13.2.5 The RA report is to:

(a) Identify the standards used for analysis and system design.
(b) Identify the engine, its purpose and the associated objectives of the analysis.
(c) Identify any assumptions made in the analysis.
(d) Identify the equipment, system or sub-system, mode of operation and the equipment.
(e) Identify potential failure modes and their causes.
(f) Evaluate the local effects (e.g. fuel injection failure) and the effects on the system as a whole (e.g. loss of propulsion power) of each failure mode.

(g) Identify measures for reducing the risks associated with each failure mode (e.g. system design, failure detection and alarms, redundancy, quality control procedures for sourcing, manufacture and testing, etc.).
(h) Identify trials and testing necessary to prove conclusions.

13.2.6 In an electronically controlled engine, it is necessary to define the essential services on which the operation of the engine relies, and the control functions, alarm functions and safety functions for the equipment and machinery providing these services. Examples of essential services are:

(a) Starting arrangements.
(b) Fuel supply arrangements.
(c) Lubricating oil arrangements.
(d) Hydraulic oil arrangements.
(e) Cooling arrangements.
(f) Power supply arrangements.

13.2.7 Where emergency engines are used as harbour sets, the system is to comply with the requirements of *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.6*. This function is to be included in the RA.

13.2.8 At sub-system level, it is acceptable to consider failure of equipment items and their functions, e.g. failure of a pump to produce flow or pressure head. It is not required that the failure of components within that pump be analysed, and failure need only be dealt with as a cause of failure of the pump.

13.3 Control engineering systems

13.3.1 Control, alarm, monitoring, safety and programmable electronic systems are to comply with *Vol 2, Pt 9 Electrotechnical Systems* and *Vol 2, Pt 10 Human Factors*, as applicable.

13.3.2 The engine control, alarm, monitoring and safety systems are to be configured to comply with the relevant requirements (e.g. operating profile, alarms, shutdowns, etc.) of this Chapter and *Vol 2, Pt 9 Electrotechnical Systems* and *Vol 2, Pt 10 Human Factors* for an engine for main, auxiliary or emergency power purposes. Details of the engine configuration are to be submitted for consideration, *see Vol 2, Pt 2, Ch 1, 2.2 Submission requirements 2.2.1*.

13.4 Software

13.4.1 Software lifecycle activities are to be carried out in accordance with an acceptable quality management system, *see* .

13.4.2 Appropriate safety related processes, methods, techniques and tools are to be applied to software development and maintenance by the engine packager or system integrator. Selection and application of techniques and measures in accordance with Annex A of IEC 61508-3, *Functional safety of electrical/electronic/programmable electronic systems: Software requirements*, or other relevant standards or codes acceptable to LR, will generally be acceptable.

13.4.3 To demonstrate compliance with *Vol 2, Pt 2, Ch 1, 13.4 Software 13.4.1* and *Vol 2, Pt 2, Ch 1, 13.4 Software 13.4.2*:

(a) software quality plans and safety evidence are to be submitted for consideration, *see Vol 2, Pt 2, Ch 1, 2.2 Submission requirements 2.2.2* and *Vol 2, Pt 2, Ch 1, 2.2 Submission requirements 2.2.2*; and
(b) an assessment inspection of the engine packager's or system integrator's completed development is to be carried out by LR. The inspection is to be tailored to verify application of the standards and codes used in software safety assurance accepted by LR.

13.5 Emergency engines

13.5.1 Electronically controlled engines will only be accepted for use as emergency engines when the additional requirements of this sub-Section are satisfied.

13.5.2 The use of electronically controlled engines for emergency power purposes will only be permitted if specified by the Naval Administration.

13.5.3 Electrically powered control equipment required for engine starting or operation is to be served by not less than two individual power supplies, one fed from a main switchboard circuit and one from an emergency switchboard circuit provided in accordance with *Vol 2, Pt 2, Ch 1, 13.5 Emergency engines 13.5.4* and *Vol 2, Pt 2, Ch 1, 13.5 Emergency engines 13.5.5*.

13.5.4 Each power supply is to be provided with an Uninterruptible Power System (UPS) in accordance with *Vol 2, Pt 9, Ch 3, 7.3 Uninterruptible power systems* capable of supplying the starting arrangements for three successive starts over a period of at least 30 minutes. A manual supply changeover switch is to be provided

13.5.5 The power supplies are not to pass through a common switchboard or section board and are not to use common feeders, protective devices, control circuits, controlgear assemblies or battery chargers, so that any single fault will not cause the loss of both supplies. Where adequate circuit protection and stored battery and charging capacity exists, the engine starting batteries may be used to provide one supply.

13.5.6 Where the proposed arrangement of engine electronic control systems do not incorporate redundancy to satisfy the requirements of *Vol 2, Pt 2, Ch 1, 13.2 Risk Assessment (RA) 13.2.1*, evidence is to be submitted that demonstrates the arrangements have been assessed and found to comply with IEC 61508, functional safety of electrical/electronic/programmable electronic systems, or a relevant alternative standard. The submissions are to include proposals for LR to verify compliance (reviews, Surveys, trials, etc.) with the applicable standard(s).

■ Scope

The requirements of this Chapter are applicable to the design and construction philosophy for gas turbine packages for main propulsion and, where powers exceed 110 kW, to those for services being provided by Mobility systems or Ship Type systems.

This Chapter details the requirements for subsystems and equipment within the boundary of the gas turbine package for either a direct mechanical drive installation or an integrated electrical power generation system.

Approval will be in respect of the mechanical integrity of the gas turbine (including gas generator and power turbine), intake and exhaust ducting configuration, acoustic enclosure configuration (where appropriate), fuel, lubricating oil and starter systems, control, monitoring, alert and safety systems, and other critical support systems.

The gas turbine bare engine is to be designed and manufactured in accordance with a relevant International or National Standard acceptable to Lloyd’s Register (hereinafter referred to as ‘LR’).

■ *Section 1*
General requirements

1.1 Definitions

1.1.1 For the purposes of this Chapter, a gas turbine package is part of a larger system (e.g. the propulsion system) providing power for main propulsion, manoeuvring and/or other Mobility systems and Ship Type systems and is considered to be a series of elements, including all equipment and associated sub-systems necessary to provide specified functions within the intended context of use in the system.

1.1.2 The principal elements of a gas turbine package are:

(a) The gas turbine unit, comprising:

- gas generator (inlet, compressor, combustion system, etc.);

- power turbine;
- engine management bleed air system;
- accessory gearbox and
- HP fuel systems.

(b) The on-engine instrumentation and engine control system, the means for monitoring, control and protection of the gas turbine, comprising:

- hardware, sensors, control cables, processors and cabinets and
- software.

(c) The gas turbine package installation, comprising:

- mounting arrangements that support the gas turbine to maintain shaft alignment and which provide the required levels of shock/vibration/noise attenuation; where appropriate, this includes the base frame mounts;
- package enclosure (where provided), including, where appropriate, the base frame supporting the gas turbine unit (and alternator);
- package drains;
- arrangements for lubricating the gas turbine unit and, where relevant, the alternator;
- arrangements for air cooling of gas turbine and equipment;
- combustion air inlet plenum and exhaust collector;
- gas turbine start system (off-unit components);
- fire protection arrangements (covering detection, containment and suppression of fire);
- intercooler and recuperator systems fitted to the gas turbine;
- combustion air filtration and arrangements to prevent ingestion of foreign objects;
- package control system, the means for monitoring, control and protection of the package, including arrangements for maintaining its power supply against loss of ship's supply.

(d) For an integrated gas turbine generator unit, the gas turbine package also includes:

- alternator, including arrangements for its ventilation/cooling and bearing lubrication and for voltage/frequency control plus
- high speed coupling shaft (alternator drive shaft).

1.1.3 A gas turbine system consists of the gas turbine unit plus its control, monitoring, alert and safety systems. *See Vol 2, Pt 2, Ch 2, 1.1 Definitions 1.1.2* and *Vol 2, Pt 2, Ch 2, 1.1 Definitions 1.1.2*.

1.1.4 Mobility and/or Ship Type support services/ship interfaces include:

(a) combustion air supply ducting;
(b) exhaust ducting;
(c) provisions for package ventilation/air cooling;
(d) ship's cooling water supply;
(e) ship's drains;
(f) fuel supply system;
(g) electrical power supplies for engine operation, including connections to/from uninterruptible power supplies;
(h) appropriate connections with the ship's control, monitoring, alert and safety systems for remote monitoring/control of the gas turbine package;
(i) provision to duct away engine bleed air and
(j) arrangements for wet washing gas turbines, supply of washing water and detergents/cleaning agents, and collection arrangements for dirty wash water.

1.1.5 Safety critical systems/components are those which provide functions intended to protect persons from physical hazards caused by engineering system failures, e.g. fire, explosion, or to prevent mechanical damage which may result in the loss of a Mobility Category System.

1.1.6 A Platform Management System provides centralised access to the ship's control, monitoring, alert and safety system functionalities.

1.2 Standard reference conditions

1.2.1 Where power, efficiency, heat rate or specific consumption refer to standard conditions (ISO 2314), such conditions are to be:

(a) for the intake air at the compressor flange (compressor intake flare):

- a total pressure of 101,3 kPa;
- an ambient temperature of 15°C;
- a relative humidity of 60 per cent; and

(b) for the exhaust at the turbine exhaust flange (or recuperator outlet):

- a static pressure of 101,3 kPa.

■ *Section 2* Functional requirements

2.1 Functional requirements

2.1.1 The gas turbine package is to operate safely to provide power to ship systems as and when required by the command whilst remaining within the designed or imposed limitations.

■ *Section 3* Performance requirements

3.1 Performance requirements

3.1.1 The gas turbine package is to be designed and constructed to operate in all normal and reasonably foreseeable abnormal operating and fault conditions.

3.1.2 The choice of materials and components of construction, as well as the design, location and ship installation, is to be made according to the environmental, maintenance and operating conditions in order to ensure the continued function of the equipment during all normal and reasonably foreseeable abnormal operating and fault conditions and to reduce the risk of:

- injury to embarked personnel;
- damage to the equipment, the system it is contained within or adjacent equipment and systems;
- damage to the ship;
- damage to third parties;
- pollution of the environment.

3.1.3 Systems supplying the gas turbine package shall be continuously available or recoverable without compromising the safety of the gas turbine system following a single operational action or system/equipment fault.

3.1.4 Where the gas turbine package is required for the provision of Mobility systems or Ship Type systems, the availability of these systems is to be maintained by means of:

- reliability, especially of any single points of failure and taking into account factors such as erosion, fatigue, corrosion and mechanical damage due to vibration; and/or
- redundancy to minimise single points of failure, this is to be supported by the engineering safety and justification report required by *Vol 2, Pt 2, Ch 2, 5.2 Documentation 5.2.8*.

3.1.5 The design, construction, installation and operation of the gas turbine package are to minimise the risk of fire.

3.1.6 The design, construction, installation and operation of the gas turbine package are not to cause interference or excessive forces that could lead to its failure or failure of other equipment and systems.

3.1.7 The gas turbine package is to be capable of continuous operation at its maximum rating in the conditions defined in *Vol 2, Pt 1, Ch 3, 4 Operating conditions* or the ship's ConOps, whichever is the more onerous. Partial reductions in capability for operation in defined extreme conditions are subject to special consideration and the agreement of the Owner; provided Mobility systems and Ship Type systems are maintained at a declared performance level acceptable to LR and the Owner.

3.1.8 The materials of the gas turbine package and its components are to have adequate strength and adequate corrosion resistance for the stated design life with clearances appropriate to the operating temperatures.

3.1.9 The design of the gas turbine package, and the design of any fixed or portable equipment supplied to support maintenance and repair activities, is to be such that all maintenance and repair activities, including 'upkeep by exchange', can be undertaken effectively and safely.

3.1.10 Safe access is to be provided to the gas turbine package, including access provision in the event of equipment failure, fault finding and diagnostics.

3.1.11 The gas turbine package is to be provided with arrangements for control, monitoring, alert and safety systems that will maintain the package in a safe state throughout all normal and reasonably foreseeable abnormal operating and fault conditions.

3.1.12 All control, monitoring, alert and safety systems are to be compatible with, and be capable of interfacing with, the ship's Platform Management System.

3.1.13 Noise and vibration from the gas turbine package are to be attenuated to requirements of an appropriate standard, agreed by the Naval Administration.

3.1.14 The environmental conditions and atmosphere of the space containing the gas turbine unit are to be maintained during all normal and reasonably foreseeable abnormal operating and fault conditions, in a range which is acceptable for Operators and appropriate to equipment installed in the space.

3.1.15 Operators are to be provided with adequate information and instructions for the safe operation and maintenance of the gas turbine package, including information on potential failures that could lead to hazardous or major consequences and degradation in systems performance that could lead to failures.

■ *Section 4*
Verification requirements

4.1 Verification requirements

4.1.1 Compliance with the requirements in Sections 5 to 12 inclusive is deemed to satisfy the functional requirements and performance requirements above.

4.1.2 Where a designer offers a novel solution for which the requirements in Sections 5 to 12 are considered inappropriate, the designer may submit the novel solution to LR for consideration with a report setting out the justification that the functional requirements in *Vol 2, Pt 2, Ch 2, 2 Functional requirements* and the performance requirements in *Vol 2, Pt 2, Ch 2, 3 Performance requirements* have been satisfied.

■ *Section 5*
Documentation required for design review

5.1 General

5.1.1 Unless otherwise advised, it is the responsibility of the system integrator or packager to agree the scope, functional requirements and boundary interfaces for the gas turbine package with LR and to prepare and submit the information required by this Chapter.

5.1.2 The following should be read in conjunction with *Vol 2, Pt 1, Ch 3, 3 Documentation required for design review*.

5.1.3 During the life of the gas turbine, details of any proposed changes that affect the safe and reliable operation of the gas turbine are to be submitted to LR for approval.

5.1.4 Where considered necessary by LR, additional documentation may be required.

5.2 Documentation

5.2.1 A System Operational Concept document covering the propulsion system, *see Vol 2, Pt 1, Ch 3, 3.4 System operational concept*.

5.2.2 A System Design Description, *see Vol 2, Pt 1, Ch 3, 3.5 System design description*, for the gas turbine package, including references to the System Operational Concept document required by *Vol 2, Pt 2, Ch 2, 5.2 Documentation 5.2.1* and to Plans required by *Vol 2, Pt 2, Ch 2, 5.2 Documentation 5.2.4*, is to be submitted so that the function of all Mobility, Ship Type and safety critical components and systems necessary for the turbine operation is clearly defined. This is to include a general overview of the operating principles supported by schematics explaining the functionality of individual systems and sub-systems. The information is to relate to the gas turbine capability and functionality under defined normal and reasonably foreseeable abnormal operating and fault conditions such as recovery from a failure, degraded modes of operation, or malfunction, with particular reference to the functioning of the control, monitoring, alert and safety systems and any subsystems.

5.2.3 Where a gas turbine unit may be required to operate for continuous periods outside its recommended continuous operating design envelope, details of the intended operating conditions, time intervals and frequency of use together with documentary evidence indicating the suitability of the design and any limitations under these conditions are to be included in the System Design Description required by *Vol 2, Pt 2, Ch 2, 5.2 Documentation 5.2.2*. Arrangements may include time alongside, manoeuvring, close-down and other military operations or trials.

5.2.4 To assess compliance with the design requirements of the Rules and for inspection, installation and record purposes, the following are to be submitted for consideration:

(a) Plans:

- Casing construction arrangement;
- Arrangements of combustion chambers, intercoolers and heat exchangers;
- Gas generator rotating components;
- Control engineering systems, *see Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*;
- Inlet and exhaust ducting arrangement;
- Nozzles, blades and blade attachments;
- Power turbine components;
- Rotors, bearings and couplings;
- Section assembly;
- Securing arrangement, where applicable, including details of resilient mounts, *see also Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.5*;
- Details of bleed air, anti-stall and surge systems or devices;
- Details of materials of all load bearing and torque transmitting components and pressure retaining parts;
- Details of materials for rotors and discs are to be submitted for approval;

(b) Schematics:

- Cooling and sealing air arrangements for compressor and gas generator components;
- Cooling water system;
- Fuel system;
- Gas turbine unit acoustic enclosure, if applicable, including fire, insulation, ventilation and drainage systems;
- Lubricating oil systems;
- Starting system;
- Machinery (safety) interlocks;

and, where applicable:

- Fire systems (Piping and Instrumentation diagram);
- Enclosure and base frame;
- Alternator;
- Highspeed coupling shaft.

5.2.5 Miscellaneous. Details of the following are also to be submitted:

(a) Operating manuals that describe the particulars of each system, including reference to the functioning of subsystems and with particular reference to any predicted adverse affects, e.g. fouling;

(b) Maintenance manuals that include declared lives of critical components and overhaul schedules recommended by the manufacturer;
(c) Fuel specifications and
(d) The maintenance and support arrangements by which the gas turbine unit is to be exchanged (where applicable).

5.2.6 Details of proposed welding procedures and proposals for the routine examination of safety-critical and/or structurally significant joints by non-destructive means are to be submitted for consideration.

5.2.7 The manufacturer's proposals for testing the gas turbine are to be submitted for consideration and are to be agreed by the Owner. These are to include details of rotor balancing techniques, methods of determining the integrity of pressure casings and heat exchanger tests.

5.2.8 An engineering safety and justification report for the gas turbine unit defined in *Vol 2, Pt 2, Ch 2, 1.1 Definitions 1.1.2*, stating design standards, assumptions and providing technical evidence. This is to be derived from a Risk Based Analysis in accordance with *Vol 2, Pt 2, Ch 2, 5.2 Documentation 5.2.9* and is to include, but is not to be limited to:

(a) Possible failure modes of internal components, to include such items as rotors, discs, seals, bearings and coupling, etc. and measures adopted to mitigate such failures that may have an effect on the internal machinery or the surrounding environment/structures/systems, taking due account of suitability of materials and the effects of stress raisers, etc.;
(b) Limiting operating parameters;
(c) Details of life-limited critical components, including their declared lives and residual lives or balance of planned life remaining, in terms of operating time or operating cycles, or where life is derived from declared acceptance criteria, and the associated maintenance strategies;
(d) Short-term high power operation;
(e) Details of mounting and securing arrangements;
(f) Rotor and blade vibratory characteristics;
(g) Details of potential failures that could lead to hazardous or major consequences and/or degradation in systems performance that could lead to failures and which are to be notified to the Operators;
(h) Common failure modes and system redundancy fitted to minimise potential single points of failure.

5.2.9 A Risk Assessment is to be carried out in accordance with the requirements of*Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)* and is to include the following associated sub-systems:

(a) Starting and stopping;
(b) Fuel;
(c) Lubricating oil;
(d) Hydraulic oil;
(e) Cooling arrangements;
(f) Intercooler, where applicable;
(g) Air induction;
(h) Exhaust;
(i) Recuperator, where applicable;
(j) Gas turbine mounting;
(k) Electrical power supplies;
(l) Control systems;
(m) Safety systems;
(n) Ventilation;
(o) Fire protection (where applicable);
(p) Emissions abatement plant;
(q) Wet washing arrangements;
(r) Rotor turning arrangements.

It is not necessary to consider failure modes relating to the gas turbine components for the purposes of this Section.

5.2.10 For the gas turbine package components and system support services defined in*Vol 2, Pt 2, Ch 2, 1.1 Definitions 1.1.2*, *Vol 2, Pt 2, Ch 2, 1.1 Definitions 1.1.2* and *Vol 2, Pt 2, Ch 2, 1.1 Definitions 1.1.5*, the engineering safety and justification report defined in *Vol 2, Pt 2, Ch 2, 5.2 Documentation 5.2.8* is to include details of potential failures that could lead to hazardous or major

consequences and/or degradation in systems' performance that could lead to failures and which are to be notified to the Operators.

5.2.11 Where applicable, the engineering safety and justification report defined in *Vol 2, Pt 2, Ch 2, 5.2 Documentation 5.2.8* is to include the fire protection arrangements specific to the package, including arrangements for the gas turbine enclosure (if provided), *see Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.15* and *Vol 2, Pt 1, Ch 3, 5.13 Fire detection, alarm and extinguishing arrangements*.

5.2.12 Where the gas turbine is a prime mover in an electrical power generation system, the engineering safety and justification report defined in *Vol 2, Pt 2, Ch 2, 5.2 Documentation 5.2.8* is to include an assessment of the systems defined in *Vol 2, Pt 2, Ch 2, 1.1 Definitions 1.1.2*, addressing requirements in *Vol 2, Pt 9 Electrotechnical Systems*.

5.2.13 In addition to the applicable plans and particulars required by *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*, the following information for control, monitoring, alert and safety systems relating to the operation of an electronically controlled unit is to be submitted:

(a) Gas turbine package configuration details, *see Vol 2, Pt 2, Ch 2, 10.11 Control engineering systems 10.11.1*;
(b) Software quality plans, including configuration management documents;
(c) Software safety evidence;
(d) Software assessment inspection report such as SCA or IEC 61508, as applicable, which is to include the following as a minimum:

- Identify the standards used for analysis and system design;
- Identify the engine, its purpose and the associated objectives of the analysis;
- Identify any assumptions made in the analysis;
- Identify the equipment, system or sub-system, mode of operation and the equipment;
- Identify potential failure modes and their causes;
- Evaluate the local effects (e.g. fuel injection failure) and the effects on the system as a whole (e.g. loss of propulsion power) of each failure mode;
- Identify measures for reducing the risks associated with each failure mode (e.g. system design, failure detection and alarms, redundancy, quality control procedures for sourcing, manufacture and testing, etc.);
- Identify trials and testing necessary to prove conclusions.

5.3 Calculations and specifications

5.3.1 The following calculations and specifications are to be submitted. Where appropriate, this information can be included in the System Design Description required by *Vol 2, Pt 2, Ch 2, 5.2 Documentation 5.2.2*:

(a) Vibration analysis and alignment analysis as required by this Chapter;
(b) The material specifications, including the minimum specified tensile strength of each shaft and coupling component, are to be stated;
(c) Details of the gas turbine manufacturer's requirements for air inlet filtration, including maximum allowable inlet pressure drop, and of the maximum allowable exhaust depression. Air intake and uptake arrangements, with calculations demonstrating that the intake and uptake designs satisfy those requirements, are to be submitted for consideration;
(d) Where a gas turbine package includes components having a specified life in terms of operating time or operating cycles, or where life is derived from declared acceptance criteria, details are to be submitted for consideration. Details of proposed arrangements for monitoring life progression are to be submitted for consideration;
(e) Statement indicating the suitability of flexible hoses;
(f) Flexible hose and bellows expansion piece registers selected for use in the package, *see Vol 2, Pt 1, Ch 3, 4.19 Flexible hose and bellows expansion piece registers*;
(g) Machinery fastening:

- Documentary evidence and calculations indicating that machinery is mounted securely for the ship's motions and accelerations, including shock, to be expected during service;
- Calculations to demonstrate that mountings can withstand the design shock acceleration without fracturing;
- Plans showing the arrangement of resiliently mounted machinery are to indicate the number, position, type and design of mounts;
- Natural frequency calculation of resiliently mounted machinery;
- Mass and centre of gravity for the gas turbine and related equipment.

5.3.2 Vibration and alignment calculations and specifications are to be submitted as part of the propulsion system requirements. *See Vol 2, Pt 3, Ch 2 Shafting Systems*.

■ *Section 6* Materials

6.1 Material tests and inspection

6.1.1 Components are to be tested in accordance with the relevant requirements of the Rules for the Manufacture, Testing and Certification of Materials (hereinafter referred to as the Rules for Materials).

6.1.2 For components of novel design, special consideration will be given to the material test and non-destructive testing requirements.

■ *Section 7* Design and construction

7.1 General requirements

7.1.1 **Application.** This Chapter is to be read in conjunction with the requirements of *Vol 2, Pt 1, Ch 1 General Requirements for Classification of Engineering Systems* and*Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*.

7.1.2 **Basic requirements.** Designs are to take account of the potential effects of system and component malfunction and variability in characteristic values.

7.1.3 The design shall account for the operating conditions specified in *Vol 2, Pt 1, Ch 3, 4 Operating conditions* or the ship's ConOps, whichever is the more onerous, and is to include those for static and dynamic loads and deflections, including for relative motions between elements of the gas turbine package and with the ship and other equipment, due to thermal expansion, vibration, etc. over all normal and reasonably foreseeable abnormal operating and fault conditions, including for fault condition loadings arising in the propulsion shaft line/alternator.

7.1.4 The gas turbine unit is to be capable of operating at defined power ratings with a range of fuel compositions/grades specified by the Owner/Operator and agreed by the gas turbine manufacturer.

7.1.5 The space containing the gas turbine unit shall comply with the requirements of *Vol 2, Pt 1, Ch 3, 5 Machinery space arrangements*.

7.1.6 Where applicable, the mounting/support arrangements of the gas turbine system are to satisfy the shock capability requirements defined by the Naval Administration. *See Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.10*.

7.1.7 The fatigue life of dynamically loaded components is to be considered with respect to defined operating conditions, expected usage and maintenance policy, *see Vol 2, Pt 2, Ch 2, 12 Planned maintenance and condition monitoring procedures, and 'upkeep by exchange'*. Due account is to be taken of stress raisers and material properties.

7.1.8 Primary exhaust gas emissions abatement plant (where fitted) is to meet the requirements of this Chapter; additionally, it is to meet those of *Vol 2, Pt 12, Ch 1 Emissions Abatement Plant for Combustion Machinery*. Where secondary exhaust gas emissions abatement systems are fitted to gas turbines, they are to meet the requirements of *Vol 2, Pt 12, Ch 1 Emissions Abatement Plant for Combustion Machinery*.

7.2 Vibration

7.2.1 The gas generator and power turbine rotors are not to exhibit levels of vibration within the normal speed range that exceed the requirements of the Owner or that result in a failure to meet engine design life.

7.2.2 Vibration monitoring is to form an integral part of the gas turbine control, monitoring, alert and safety system. The vibration monitoring system is to be capable of detecting the out-of-balance of major parts with means being provided to shut down the gas turbine, before an over-critical situation occurs, i.e. multiple rotor blade or disc release.

7.3 Containment

7.3.1 Gas turbines and power turbines are to be designed and installed to contain debris within the unit in the event of release of a rotor blade or other rotating component of equivalent kinetic energy on release.

7.3.2 In the event of any component failure where the engine casing may not contain the debris, fuel, lubricating oil and other potentially hazardous systems or equipment are to be located outside the planes of those high-speed rotating parts identified as a potential loss of containment hazard by the engineering safety and justification report. Where this is not possible, they are to be suitably protected. This requirement also applies to fire detection and fire-extinguishing equipment.

7.3.3 Gas turbine ancillaries containing flammable products are to be segregated or protected from high temperature areas.

7.3.4 Means are to be provided such that, in the event of a failure to a shaft or coupling, the occupants of the ship are not endangered, either directly or through damage to the ship or its systems. Where necessary, guards may be fitted to achieve compliance with these requirements.

7.4 Intake and exhaust ducts

7.4.1 The air intakes and exhausts are to be in accordance with the turbine manufacturer's design requirements. Particular attention is drawn to the requirements on pressure and flow conditions to be achieved throughout the intake and exhaust systems. Arrangements are to comply with *Vol 2, Pt 2, Ch 2, 7.4 Intake and exhaust ducts 7.4.2* to *Vol 2, Pt 2, Ch 2, 7.4 Intake and exhaust ducts 7.4.13*, as applicable.

7.4.2 Where multiple gas turbines are installed, each gas turbine unit is to have separate intakes and exhausts so arranged as to prevent induced circulation through a stopped gas turbine unit.

7.4.3 Intakes and exhausts are to include suitable means of access to carry out inspections, maintenance and/or repair of components as advised by the gas turbine manufacturer. Any access panels should be sealed suitably to maintain the desired pressure and flow conditions in the intake and exhaust.

7.4.4 Suitable intake filtration is to be provided to control the ingestion of water, particulate and corrosive marine salts within the gas turbine manufacturer's specified limits.

7.4.5 Where an air intake enclosure forms the connection between the ship's downtake and the gas turbine package, a suitable alarm function is to be provided to give warning when an unacceptable air intake pressure loss is reached at the air inlet (bellmouth) of the gas turbine.

7.4.6 Intakes are to be designed such that material cannot become detached due to air flow or corrosion. Fixing bolts and fastenings are to be positively locked so that they cannot work loose.

7.4.7 The exhaust system is to accommodate thermal expansion and movement of the duct due to the combined effects of operation of the gas turbine and flexure of the ship's structure.

7.4.8 The design of exhaust systems is to prevent deterioration of engine parts resulting from ingress of sea or rainwater through the exhaust ducting when the gas turbine is not in use. Drainage arrangements are to be provided and are to be led to a tank suitable for the potentially corrosive nature of any drainage.

7.4.9 The exhaust ducting is to be designed and installed to minimise the risk of unburnt fuel collecting inside the duct.

7.4.10 The arrangement of the exhaust system is to be such as to prevent exhaust gases being drawn into the manned spaces, air conditioning systems and air intakes.

7.4.11 The exhaust system is to be arranged so that hot exhaust gases are directed to avoid impingement on equipment and away from areas to which personnel have access, either on board or in the vicinity of where the craft is berthed.

7.4.12 Where the exhaust is led overboard near the waterline, means are to be provided to prevent water from being siphoned back into the gas turbine. Where the exhaust is cooled by water spray, the exhaust pipes are to be self-draining overboard. Erosion/corrosion-resistant shut-off flaps or other devices are to be fitted on the hull side shell or pipe end with suitable arrangements made to prevent water flooding the machinery space.

7.4.13 The design of exhaust systems is to take account of any noise hazards to personnel, ensuring that they are within specified requirements for the ship.

7.4.14 The design of exhaust gas waste heat recovery recuperators for combustion air heating is to be compatible with the installed engine design parameters. The parameters which influence the build up of soot deposits and overheating such as fuel, exhaust gas temperature and efflux velocity are to be considered in the design of the recuperator in order to minimise the risk of fire and breakdown during operation. The engineering safety and justification report required by *Vol 2, Pt 2, Ch 2, 5.2*

Documentation 5.2.8 is to also demonstrate compliance with these requirements or alternative means of preventing the accumulation of soot or overheating, such as the use of exhaust gas by-pass ducting with automatic flap valve arrangements and/or effective soot prevention and cleaning systems for installations which use recuperators. Waste heat recovery units for steam generation are to meet the requirements of *Vol 2, Pt 8, Ch 1, 1.13 Exhaust gas economiser/boiler arrangements*.

7.5 Thermal insulation

7.5.1 Suitable provision is to be made to protect personnel and equipment and to minimise the risk of fire from any surfaces of the gas generator, power turbine and/or exhaust volute that exceed a temperature of 220°C during operation.

7.6 Welded construction

7.6.1 Welding processes are to be in accordance with the requirements of the Rules for Materials.

7.7 Anti-stall/surge systems

7.7.1 Air bleed (blow off) valves and/or variable geometry mechanisms are to be fitted as required to maintain compressor surge margins throughout the operating range. Any open-ended air bleed arrangements are to be led to the uptake or atmosphere and not into the machinery space; the back pressure imposed by the ducting is to be in accordance with the turbine manufacturer's recommendations.

7.7.2 The design of anti-surge and anti-stall systems is to take account of any noise hazards to personnel, ensuring they are within specified requirements for the ship.

7.8 Emergency operation

7.8.1 Where a gas turbine is required for the provision of Mobility systems or Ship Type systems, it and its supporting service systems are to be capable of operation when the compartment is flooded to the level of the underside of the lowest exposed portion of the gas turbine casing.

■ *Section 8*
Gas turbine package sub-systems

8.1 Piping systems

8.1.1 Gas turbine piping systems are, in general, to comply with the requirements given in *Vol 2, Pt 7, Ch 1 Piping Design Requirements* and *Vol 2, Pt 7, Ch 3 Machinery Piping Systems*, due regard being paid to the particular type of installation.

8.1.2 The gas turbine design and construction are to minimise the possibility of a fire fed by fuel or lubricating oil leaks.

8.1.3 Any flexible hose assemblies are to comply with *Vol 2, Pt 7, Ch 1, 13 Flexible hoses*.

8.2 Fuel systems

8.2.1 Fuel oil arrangements are to comply with the requirements of *Vol 2, Pt 7, Ch 3, 3.9 Fuel oil treatment for supply to diesel engines and gas turbines*; gas fuel supply arrangements are to comply with the requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements*.

8.2.2 Any high-pressure fuel delivery lines between the fuel pumps and fuel metering valves that are external to the enclosure are to be of double walled construction and are to be capable of containing fuel from a high-pressure line failure to prevent fuel, or fuel oil mist, from reaching a source of ignition on the gas turbine or its surroundings.

8.2.3 Suitable arrangements are to be made for draining/venting any fuel leakage from the protection required by *Vol 2, Pt 2, Ch 2, 8.2 Fuel systems 8.2.2* and to prevent contamination of the lubricating oil by fuel oil. An alarm is to be provided to indicate that leakage is taking place.

8.2.4 Means are to be provided to purge the fuel system of air.

8.2.5 Gas turbine fuel system components are to be designed to accommodate the maximum peak pressures experienced in service. Connections on such piping systems should be chosen to minimise the risk of pressurised fuel leaks.

8.2.6 Where more than one gas turbine is supplied from the same fuel source, means of isolating the fuel supply and spill piping to individual engines are to be provided. These means of isolation are not to affect the operation of the other gas turbine(s) and are to be operable from a position not rendered inaccessible by a fire on any of the engines, *see also Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*.

8.3 Lubricating oil systems

8.3.1 Lubricating oil arrangements for the gas turbine system and, where applicable, the alternator, are to comply with the requirements of *Vol 2, Pt 7, Ch 3, 8 Lubricating oil systems*. They are to be configured to provide adequate flows of lubricating oil to all bearings in the gas turbine unit and, where applicable, the alternator, over the whole range of normal operation and reasonably foreseeable abnormal operating and fault conditions, including start-up and shutdown (run-down) periods.

8.3.2 Where the lubricating oil is circulated under pressure, provision is to be made for the efficient filtration of the oil. At least two filters are to be fitted in the lubricating oil supply lines to the gas turbine and be so arranged that any filter may be cleaned without interrupting the supply of filtered lubricating oil to the gas turbine.

8.3.3 Gas generator and power turbine bearings are to be arranged such that lubrication is not affected adversely by heat flow from adjacent hot parts. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings.

8.4 Ventilation and cooling systems

8.4.1 Air cooling and/or ventilation arrangements are to comply with the requirements of *Vol 2, Pt 1, Ch 3, 5.7 Ventilation* and *Vol 2, Pt 1, Ch 3, 5.12 Machinery enclosures*.

8.4.2 Cooling water arrangements are to comply with the requirements of *Vol 2, Pt 7, Ch 3 Machinery Piping Systems*, as applicable.

8.5 Turning gear

8.5.1 Turning gear is to be provided to facilitate operation and maintenance of the gas turbine unit as required by the manufacturer.

8.5.2 Gas generator turning gear may be hand-operated where hand operation is practicable. Where turning gear is electrically driven, the motor is to be rated continuously to turn the rotor for an indefinite period with no restrictions. Manuals are to be provided and are to comply with the requirements of *Vol 2, Pt 1, Ch 1, 4.6 Through life operation principles 4.6.7*.

8.5.3 The turning gear is to be fitted with safety interlocks which prevent gas turbine operation when the turning gear is engaged, *see Vol 2, Pt 1, Ch 3, 4.14 Machinery interlocks*. Indication of engaged/disengaged is to be provided at all start positions. In the case of hand-operated turning gear, turbine operation may be prevented by manual means, including the provision of warning devices or notices.

8.5.4 The remote control of power-driven turning gear is to be designed so that power is removed if the operating switch is released.

8.5.5 If permanently attached, means are to be provided to secure the turning gear when disengaged.

8.5.6 Overload protection arrangements are to be provided to prevent damage to the turning gear train. Where the turning gear is electrically driven, the protection system is to comply with *Vol 2, Pt 10, Ch 1 Ergonomics*.

8.6 Power take-off coupling shafts

8.6.1 Power take-off shafts coupling the power turbine to the main gearbox/generator are to comply with the requirements for such intermediate shafts given in *Vol 2, Pt 3, Ch 2 Shafting Systems*, due regard being paid to the particular type of installation.

8.7 Installation

8.7.1 Drainage arrangements for package components are to link to ship's drains, taking due account of the materials involved (wash water, fuel, lubricating oil, etc.). Where applicable, those arrangements are not to compromise any requirements to operate the space containing the gas turbine unit at pressures above/below atmospheric ambient.

8.7.2 The ventilation arrangements for the space containing the gas turbine system are to provide sufficient air flow to ensure that the temperatures of components are maintained within the limits specified by the supplier for all normal and reasonably foreseeable abnormal operating and fault conditions.

8.7.3 Where the gas turbine unit is subject to a process of 'upkeep by exchange', the lifting arrangements that form part of the installation and/or provisions for the attachment of lifting gear within the installation shall conform to the requirements of a recognised Standard for lifting appliances.

8.7.4 Machinery is to be mounted to provide adequate support against ship motions and relative movement between items of equipment and, where required, protection against shock in accordance with Naval Administration requirements, and to attenuate the transmission of noise and vibration to meet the specified requirements. The requirements of *Vol 2, Pt 1, Ch 3, 5.5 Resilient mountings*, are to be satisfied.

8.8 Fire protection

8.8.1 Where the package includes a dedicated fire protection system to protect against fire in the gas turbine unit and its ancillaries, that system is to meet the requirements of *Vol 2, Pt 1, Ch 3, 5.13 Fire detection, alarm and extinguishing arrangements*.

8.8.2 Where the gas turbine is installed inside a dedicated enclosure, the enclosure boundary is to provide an appropriate level of fire protection, containing/limiting the spread of flames and smoke. An engineering assessment of this boundary demonstrating that the installation meets the levels of fire safety demanded of the ship is to be provided as part of the Assurance Case, *see Vol 2, Pt 2, Ch 2, 5.2 Documentation 5.2.10*.

■ *Section 9*
Starting arrangements

9.1 General

9.1.1 The operating conditions under which provision for starting gas turbines is required are to be defined in the System Operational Concept document.

9.1.2 Where a gas turbine is required for the provision of Mobility systems or Ship Type systems, equipment for initial starting of the gas turbine is to be provided and arranged such that the necessary initial charge of starting air, hydraulic or electrical power can be developed on board the ship without external aid.

9.1.3 Alternatively, other devices of an approved type may be accepted as a means of providing the initial start.

9.1.4 Where the integrity of the starting system is susceptible to overspeed conditions, appropriate alarm and/or trip functions are to be provided.

9.2 Purging before ignition

9.2.1 Means are to be provided to clear all parts of the gas turbine of any accumulation of fuel before ignition commences on starting, or recommences after failure to start. The purge is to be of sufficient duration to displace at least three times the volume of the exhaust system.

9.3 Air starting

9.3.1 Air starting arrangements are to meet the requirements of *Vol 2, Pt 7, Ch 3, 12 Air compressors and air starting arrangements*. Exhaust from the start air system is to be arranged so as not to present a hazard to the crew.

9.4 Electric starting

9.4.1 Where the gas turbine is arranged for electric starting, the arrangement is to be equipped with two independent power sources with one source protected against depletion. In all cases the electrical systems forming the starting system are to comply with the requirements of *Vol 2, Pt 9 Electrotechnical Systems*.

9.5 Hydraulic starting

9.5.1 Where the gas turbine is arranged for hydraulic starting, then either the hydraulic pressure capacity of the power pack is to be sufficient to provide the number of starts of the gas turbine as required by *Vol 2, Pt 2, Ch 2, 9.3 Air starting 9.3.1* or the hydraulic power pack is to be supplied by two independent sources of electrical power, one of which is to be suitably protected against depletion.

Section 10
Control, monitoring, alert and safety systems

10.1 General

10.1.1 Control, monitoring, alert, safety and programmable electronic systems are to comply with the requirements of this Section and *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*.

10.1.2 The control system is to ensure safe and effective operation of the gas turbine package through the monitoring and control of critical parameters, such as engine speed, temperatures and pressures.

10.1.3 Each gas turbine is to be configured for the specified performance and is to satisfy the relevant requirements for mechanical drive or electrical generator applications.

10.1.4 The arrangements for control, monitoring, alert and safety systems are to be provided with a suitable back-up power supply to ensure that the gas turbine package can be shut down in a safe and controlled fashion upon loss of its primary and, where applicable, secondary electrical power supplies.

10.1.5 Interlocks are to be provided to prevent any operation of the gas turbine unit under conditions that could be hazardous to the machinery and/or personnel. The interlock system is to be arranged to be 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis of the complete installation.

10.2 Overspeed protection and shutdown system

10.2.1 The gas turbine is to be protected against overspeed by the provision of a suitable device(s) and software functions capable of shutting down the gas turbine safely before a hazardous overspeed condition occurs.

10.3 Speed governors

10.3.1 For each gas turbine that provides mechanical drive to propulsion device(s), a speed governor independent of the overspeed protective device is to be fitted. The speed governor's set limits are to be adjusted so that the speed does not exceed the limits which bring the overspeed protective device into action, *see Vol 2, Pt 2, Ch 2, 10.2 Overspeed protection and shutdown system 10.2.1*.

10.3.2 For each gas turbine intended for driving an electric generator, a speed governor, independent of the overspeed protective device is to be fitted. The speed governor's fixed settings are to control the gas turbine speed within the design limits of the electrical system requirements, as defined in the electrical System Operational Concept document.

10.4 Power turbine inlet over-temperature control

10.4.1 The power turbine is to be protected against over-temperature by the provision of a suitable device(s) capable of controlling the temperature within acceptable limits or shutting down the gas turbine safely to prevent damage.

10.5 Flame out

10.5.1 Indication is to be provided for identifying flame out and failure to ignite conditions for each combustion chamber, *see also Vol 2, Pt 2, Ch 2, 9.2 Purging before ignition 9.2.1*.

10.6 Lubricating oil system

10.6.1 Means are to be provided to determine accurately the pressure or flow of the lubricating oil supply to the various parts of the gas generator and power turbine, and scavenge oil and return systems, to ensure safe operation.

10.6.2 Means are to be provided to determine accurately the temperature of the lubricating oil supply to the various parts of the gas generator and power turbine, and scavenge oil and return systems, to ensure safe operation.

10.6.3 Means are to be provided to ensure that the temperature of the lubrication oil supply is controlled automatically to maintain steady-state conditions throughout the normal operating range of the gas turbine.

10.6.4 Where the lubrication oil supply to the power turbine is fed from a separate supply system, similar arrangements to those detailed above are to be provided.

10.7 Stopping of gas turbines

10.7.1 Means are to be provided, at both the local and remote control/operating positions, to initiate manually the shutdown of the gas turbine in an emergency.

10.7.2 In addition to *Vol 2, Pt 2, Ch 2, 10.7 Stopping of gas turbines 10.7.1*, a means of manually shutting off the fuel in an emergency is to be provided at the manoeuvring station where the station is remote from the gas turbine control/operating position.

10.7.3 *See also Vol 2, Pt 1, Ch 3, 4.15 Stopping of machinery* for requirements for stopping machinery from a position outside the compartment where the machinery is located.

10.8 Indication of temperature

10.8.1 Means are to be provided for indicating the temperature of power turbine exhaust gases.

10.9 Automatic and remote controls

10.9.1 Where gas turbines are fitted with automatic or remote controls so that under normal operating conditions they do not require manual intervention by the Operators, they are required to be provided with alarm and safety arrangements required by *Vol 2, Pt 2, Ch 2, 10.9 Automatic and remote controls 10.9.2* and *Table 2.10.1 Gas turbine machinery: Alarms and shutdowns*, as appropriate. Alternative arrangements which provide an equivalent level of safety will be considered.

Table 2.10.1 Gas turbine machinery: Alarms and shutdowns

Item	Alarm	Note
Overspeed	High	Automatic shutdown, *see also Vol 2, Pt 2, Ch 2, 10.2 Overspeed protection and shutdown system*
Power turbine inlet temperature	1st stage high	Automatic power reduction
See Note 4	2nd stage high	Automatic shutdown, *see also Vol 2, Pt 2, Ch 2, 10.4 Power turbine inlet over-temperature control*
Flame failure	Failure	Automatic shutdown, *see also Vol 2, Pt 2, Ch 2, 10.5 Flame out*
Failure to ignite	Failure	Automatic shutdown, *see also Vol 2, Pt 2, Ch 2, 10.5 Flame out*
Turbine vibration	1st stage high	–
	2nd stage high	Automatic shutdown
Uptake temperature	High	To monitor for soot fires *See* Notes 5 and 6

Note 1 For two-stage alarms, *see also Vol 2, Pt 2, Ch 2, 10.9 Automatic and remote controls 10.9.3*.

Note 2 For requirements on purging before ignition, *see Vol 2, Pt 2, Ch 2, 9.2 Purging before ignition*.

Note 3 Where there are separate lubricating oil systems for gas generator and power turbine/gearing sections, each system is to be monitored.

Note 4 Where there is more than one combustion chamber, the temperature of each chamber is to be monitored.

Note 5 Alarm only required when suitable for operation on residual fuel grades and an exhaust gas economiser/boiler/thermal oil heater is fitted.

Note 6 Alternatively, details (including location) of an appropriate fire detection system are to be submitted for consideration.

Note 7 The Table contains the minimum list of alerts and shutdowns for a gas turbine; additional alerts and shutdowns may be necessary as determined through risk-mitigating activities in response to the completed Risk-Based Analysis (e.g. FMECA) for the gas turbine.

Note 8 If certain alarms and shutdowns are not applicable for the gas turbine, sufficient evidence shall be produced to support the claim (e.g. Risk-Based Analysis such as FMECA).

10.9.2 Where fuel oil grades require heating or cooling only, fuel oil supply is to be fitted with automatic temperature controls so as to maintain steady state conditions throughout the normal operating range of the turbine, *see also Vol 2, Pt 2, Ch 2, 10.9 Automatic and remote controls 10.9.4*.

10.9.3 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery are required in *Table 2.10.1 Gas turbine machinery: Alarms and shutdowns*, the sensors and circuits utilised for the second stage alarm and automatic shutdown are to be functionally independent of those required for the first stage alarm, in that failure in one cannot affect the functionality of the other.

10.9.4 Where the fuel oil supply is heated, automatic control for viscosity may be fitted in place of the temperature control required by *Vol 2, Pt 2, Ch 2, 10.9 Automatic and remote controls 10.9.2*.

10.10 Sensors

10.10.1 Sensors are to be selected with regard to their accuracy and integrity. For measurements required for safety functions, an engineering assessment is to be presented justifying the sensor configuration adopted. This assessment is to address any self-testing by the control system that is used to monitor the health of those sensors.

10.10.2 Where multiple sensor arrays are used to provide the necessary levels of reliability and integrity, the control system is to use the value that provides the greatest margin of safety.

10.11 Control engineering systems

10.11.1 The engine control, monitoring, alert and safety systems are to be configured to comply with the relevant requirements (e.g. operating profile, alarms, shutdowns, etc.) of this Chapter and *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems* for an engine for main or auxiliary power purposes. Details of the engine configuration are to be submitted for consideration identifying:

(a) Local and remote means to carry out system configuration.
(b) Engine packager or system integrator procedures for undertaking configuring.
(c) Roles and responsibilities for configuration (e.g. Enginebuilder, engine packager, system integrator or other nominated party) with accompanying schedule.
(d) Configurable settings and parameters (including those not to be modified from a default value).
(e) Configuration for propulsion or auxiliary engine application.

Configuration records are to be maintained and are to be made available to the Surveyor at testing and trials and on request, in accordance with *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*.

10.12 Software

10.12.1 Where a software-based system forms part of a control, monitoring, alert and safety system, it is to comply with the requirements of *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems* & *Vol 2, Pt 9, Ch 8 Programmable Electronic Systems*.

■ *Section 11*
Survey and testing

11.1 Construction principles

11.1.1 Construction is to be in accordance with plans approved by LR and in accordance with the requirements of the relevant parts of the Rules, *see Vol 2, Pt 1, Ch 3, 8 Gas turbines*.

11.1.2 Where required by these Rules, items are to be constructed under survey.

11.1.3 Materials are to be approved, manufactured and tested in accordance with a standard acceptable to LR.

11.1.4 Satisfactory operation and load testing is to be witnessed by LR where required by the Rules.

11.1.5 The elements of the package listed in *Table 2.11.1 Gas turbine machinery: Certification requirements* are, as applicable, to be certified as shown.

Table 2.11.1 Gas turbine machinery: Certification requirements

Component	Certificate	Standards
Gas turbine unit	Type Approval Certificate Engine Construction Certificate	LR Test Spec GTA04 Naval Ship Rules
Engine fluid systems	Design Appraisal Document Package Construction Certificate	Naval Ship Rules
GT Lubrication Module	Design Appraisal Document Equipment Certificate	Naval Ship Rules
Fuel systems	Design Appraisal Document Equipment Certificate	Naval Ship Rules
Control System Hardware	Type Approval Certificate Type Test Certificate	LR Test Spec 01
Control System Software	Design Appraisal Document Package Construction Certificate	LR Software Conformity National Standards Naval Ship Rules
Engine Mounts	Design Appraisal Document Equipment Certificate	Naval Ship Rules
Package Mounts	Manufacturer’s Certificate	National Standards
Enclosure and Base frame (as appropriate)	Design Appraisal Document Package Construction Certificate	Naval Ship Rules SOLAS
Cooling/ventilation systems	Design Appraisal Document Package Construction Certificate	Naval Ship Rules National Standards
Fire protection system (FPS)	Design Appraisal Document Type Approval Certificates Package Construction Certificate	Naval Ship Rules SOLAS FSS Code
Fire Insulation Arrangements	Design Appraisal Document Type Approval Certificates Package Construction Certificate	Naval Ship Rules FTP Code
Start system	Design Appraisal Document Equipment Certificate	Naval Ship Rules
Intake assembly	Manufacturer’s Certificate	National Standards
Exhaust collector	Manufacturer’s Certificate	National Standards
Coupling shaft (where applicable)	Design Appraisal Document Equipment Certificate	Naval Ship Rules
Alternator Lubrication Module (where applicable)	Design Appraisal Document Equipment Certificate	Naval Ship Rules

■ Section 12
Planned maintenance and condition monitoring procedures, and 'upkeep by exchange'

12.1 Planned maintenance approach

12.1.1 Suitable gas turbine package, Planned Maintenance and Condition Monitoring Schemes (PMS(CM)), will be accepted as part of LR's Continuous Survey Machinery (CSM) cycle, provided the principles defined in *Vol 2, Pt 2, Ch 2, 12.2 Preventive maintenance* are satisfied.

12.2 Preventive maintenance

12.2.1 Preventive maintenance requires items to be opened for inspection by removing inspection covers or partial disassembly as appropriate, by using probes or by direct observation, and overhaul at specified time periods or after a specified number of running hours.

12.2.2 Maintenance is normally carried out irrespective of the condition of the gas turbine package components in order to retain the package in a satisfactory operational condition.

12.3 Unscheduled maintenance

12.3.1 The planned maintenance scheme is to be capable of dealing effectively with breakdown or corrective maintenance, i.e. unscheduled maintenance.

12.4 Condition monitoring

12.4.1 The conditioning monitoring techniques to support the trend away from preventive maintenance, are listed in *Table 2.12.1 Condition monitoring techniques*. They are considered the minimum acceptable to obviate the need for a fully opened out inspection of engine components at Periodical Survey.

Table 2.12.1 Condition monitoring techniques

Method	Requirement
Visual inspection	Periodic inspection of intakes and exhaust ducts, inlet guide vanes, compressor 1st stage, compressor and gas generator casings and auxiliary components and systems. The running clearances and dimensional changes, where practicable
Visual inspection by borescope/endoscope	Periodic inspection of compressor stators, guide vanes and blades, combustion chambers, turbine nozzles and blades and power turbine
Vibration monitoring	Continuous monitoring and trend analysis of gas generator and power turbine rotor vibration. The equipment used for vibration measurement should be capable of determining vibration throughout the operating range of the gas turbine
Lubrication, oil trend analysis programme	• Periodic inspection of magnetic particle detectors (manual records and/or automatic recording via debris counters in oil scavenge lines) • Periodic inspection of oil filters • Periodic sampling and laboratory analysis of lubricant quality
Fuel quality	• Maintenance of fuel oil bunker/marine gas oil analysis records • Periodic sampling and laboratory analysis of fuel quality

Performance monitoring	Continuous monitoring and trend analysis of critical gas turbine operating parameters including: • Compressor conditions (inlet and exit temperature, delivery pressure and speed) • Power turbine (inlet entry temperature and speed) • Engine breather temperature • Low cycle fatigue counter *See* Note
Note Manual recording and trend analysis methods may also be acceptable.	

12.4.2 Alternative arrangements to those in *Table 2.12.1 Condition monitoring techniques*, which provide an equivalent level of confidence in the condition of the gas turbine package, will be considered.

12.5 'Upkeep by exchange'

12.5.1 Where the gas turbine is maintained using an 'upkeep by exchange' policy, the requirements in *Vol 2, Pt 1, Ch 1, 6.10 Upkeep by exchange* are to be satisfied. Details of the arrangements by which the gas turbine unit is to be exchanged are to be submitted to LR for approval.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General Requirements for Machinery and Engineering Systems in *Vol 2, Pt 1, Ch 1 General Requirements for Classification of Engineering Systems* and *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*.

1.1.2 The requirements of this Chapter are applicable to steam turbines for main propulsion and other Mobility and/or Ship Type systems.

1.1.3 Where exhaust gas emissions abatement equipment is fitted to steam-raising plant, it is to meet the requirements of *Vol 2, Pt 12 Emissions Abatement Plant*.

1.2 Power ratings

1.2.1 In this Chapter, where the dimensions of any particular component are determined from shaft power, P, in kW, and revolutions per minute, R, the values to be used are those defined in *Vol 2, Pt 1, Ch 3, 4.3 Power ratings*.

1.3 Power conditions for generator sets

1.3.1 Auxiliary steam turbines coupled to electrical generators are to be capable under service conditions of developing continuously the power to drive the generators at full rated output and of developing for a short period (15 minutes) an overload power of not less than 10 per cent, *see Vol 2, Pt 9 Electrotechnical Systems*.

1.4 Inclination of ship

1.4.1 Main and auxiliary steam turbines for Mobility and/or Ship Type systems are to operate satisfactorily under the conditions as shown in *Table 3.4.2 Inclinations* in Pt 1, Ch 3.

■ *Section 2* Documentation required for design review

2.1 Documentation

2.1.1 The following plans are to be submitted for consideration:

- General arrangement.
- Sectional assembly.
- Rotors and couplings.

- Casings.

2.1.2 A System Operational Concept covering the Propulsion system is to be submitted, *see Vol 2, Pt 1, Ch 3, 3.4 System operational concept*.

2.1.3 A System Design Description is to be submitted (*see Vol 2, Pt 1, Ch 3, 3.5 System design description*) containing the following information:

- Particulars of materials;
- Maximum shaft powers;
- Maximum and minimum revolutions per minute;
- The pressures and temperatures applicable at maximum shaft power and under the emergency conditions of *Vol 2, Pt 2, Ch 3, 5.2 Single screw ships* are to be stated (or indicated on the plans);
- For the emergency conditions of *Vol 2, Pt 2, Ch 3, 5.3 Single main boiler*, full particulars of the means proposed for emergency propulsion.

2.1.4 In general, plans for auxiliary turbines need not be submitted.

■ *Section 3* Materials

3.1 General

3.1.1 In the selection of materials, consideration is to be given to their creep strength, corrosion resistance and scaling properties at working temperatures to ensure satisfactory performance and long life under service conditions.

3.1.2 Grey cast iron is not to be used for temperatures exceeding 260°C.

3.2 Materials for forgings

3.2.1 Turbine rotors and discs are to be of forged steel. For carbon and carbon-manganese steel forgings, the specified minimum tensile strength is to be selected within the limits of 400 and 600 N/mm^2. For alloy steel rotor forgings, the specified minimum tensile strength is to be selected within the limits of 500 and 800 N/mm^2. For discs and other alloy steel forgings, the specified minimum tensile strength is to be selected within the limits of 500 and 1000 N/mm^2.

3.2.2 For alloy steels, details of the proposed chemical composition, heat treatment and mechanical properties are to be submitted for approval.

3.2.3 When it is proposed to use material of higher tensile strength, full details are to be submitted for approval.

■ *Section 4* Design and construction

4.1 General

4.1.1 In the design and arrangement of turbine machinery, adequate provision is to be made for the relative thermal expansion of the various turbine parts, and special attention is to be given to minimising casing and rotor distortion under all operating conditions.

4.1.2 Turbine bearings are to be so disposed and supported that lubrication is not adversely affected by heat flow from adjacent hot parts of the turbine. Effective means are to be provided for intercepting oil leakage and preventing oil from reaching high temperature glands and casings and steam pipes. Drainage openings and drain pipes from oil baffle pockets are to be sufficiently large to prevent excessive accumulation and leakage of oil.

4.2 Welded components

4.2.1 Turbine rotors, cylinders and associated components fabricated by means of welding will be considered for acceptance if constructed by firms whose works are properly equipped to undertake welding to equivalent standards, for rotors and cylinders respectively, to those required by the Rules for Class 1 and Class 2/1 welded pressure vessels, *see Vol 2, Pt 1, Ch 4 Requirements for Fusion Welding of Pressure Vessels and Piping*.

4.2.2 Welding is to be carried out in accordance with the requirements of *Ch 13, 4 Specific requirements for fusion welded pressure vessels* of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) using welding procedures and welders that have been qualified in accordance with *Ch 12 Welding Qualifications* of the Rules for Materials.

4.2.3 Before work is commenced, manufacturers are to submit for consideration details of proposed welding procedures and their proposals for routine examination of joints by non-destructive means.

4.2.4 Materials used in the construction of turbine rotors, cylinders, diaphragms, condensers, etc. are to be of welding quality.

4.2.5 Where it is proposed to construct rotors from two or more forged components joined by welding, full details of the chemical composition, mechanical properties and heat treatment of the materials, together with particulars of the welding consumables, an outline of the welding procedure, method of fabrication and heat treatment, are to be submitted for consideration.

4.2.6 Joints in rotors and major joints in cylinders are to be designed as full-strength welds and for complete fusion of the joint.

4.2.7 Adequate preheating is to be employed for mild steel cylinders and components and where the metal thickness exceeds 44 mm, and for all low alloy steel cylinders and components and for any part where necessitated by joint restraint.

4.2.8 Stress relief heat treatment is to be applied to all cylinders and associated components on completion of the welding of all joints and attached structures. For details of stress relief procedure, temperature and duration.

4.2.9 For all welded components, weld procedure tests are to be in accordance with *Ch 12, 2.7 Destructive tests for steel butt welds* of the Rules for Materials.

4.2.10 Production weld tests are to be performed according to the requirements of *Ch 13, 4.5 General requirements for routine weld production tests* of the Rules for Materials.

4.3 Stress raisers

4.3.1 Smooth fillets are to be provided at abrupt changes of section of rotors, spindles, discs, blade roots and tenons. The rivet holes in blade shrouds are to be rounded and radiused on top and bottom surfaces, and tenons are to be radiused at their junction with blade tips. Balancing holes in discs are to be well rounded and polished.

4.3.2 Surveyors are to be satisfied as to the workmanship and riveting of blades to shroud bands, and that the blade tenons are free from cracks, particularly with high tensile blade material. Test samples are to be sectioned and examined, and pull-off tests made if considered necessary by the Surveyors.

4.4 Shrunk-on rotor discs

4.4.1 Main turbine rotor discs fitted by shrinking are to be secured with keys, dowels or other approved means.

4.5 Vibration

4.5.1 Care is to be taken in the design and manufacture of turbine rotors, rotor discs and blades to ensure freedom from undue vibration within the operating speed range. Consideration of blade vibration should include the effect of centrifugal force, blade root fixing, metal temperature and disc flexibility, where appropriate.

4.5.2 For the vibration and alignment of main propulsion systems formed by the turbines geared to the line shafting, *see Vol 2, Pt 5, Ch 4 Shaft Alignment*.

4.6 External influences

4.6.1 Pipes and ducts connected to turbine casings are to be so designed that no excessive thrust loads or moments are applied by them to the turbines. Gratings and any fittings in way of sliding feet or flexible-plate supports are to be so arranged that casing expansion is not restricted. Where main turbine seatings incorporate a tank structure, consideration is to be given to the temperature variation of the tank in service to ensure that turbine alignment will not be adversely affected.

4.7 Steam supply and water system

4.7.1 In the arrangement of the gland sealing system, the pipes are to be made self-draining and every precaution is to be taken against the possibility of condensed steam entering the glands and turbines. The steam supply to the gland sealing system is to be fitted with an effective drain trap. In the air ejector re-circulating water system, the connection to the condenser is to be so located that water cannot impinge on the L.P. rotor or casing.

4.8 Turning gear

4.8.1 Turning gear is to be provided for all turbines to facilitate operating and maintenance regimes as required by the manufacturer. Manuals are to be provided and are to comply with the requirements of *Vol 2, Pt 1, Ch 1, 4.6 Through life operation principles 4.6.7*.

4.8.2 The turning gear for all propulsion turbines is to be power-driven and if electric, is to be continuously rated.

4.8.3 The turning gear for all turbines is to be fitted with safety interlocks which prevent steam valve actuation for turbine operation when engaged, *see Vol 2, Pt 1, Ch 3, 4.13 Electromagnetic compatibility (EMC)*. Indication of engaged/disengaged is to be provided at all start positions. In the case of hand operated turning gear turbine operation may be prevented by manual means including the provision of warning devices or notices.

4.8.4 The remote control of power driven turning gear is to be designed so that power is removed if the operating switch is released.

4.8.5 Means are to be provided to secure the turning gear when disengaged.

4.8.6 Overload protection arrangements are to be provided to prevent damage to the electric motor and the turning gear train.

■ *Section 5*
Emergency arrangements

5.1 Lubricating oil failure

5.1.1 Arrangements are to be made for the steam to the ahead propulsion turbines to be automatically shut off in the event of failure of the lubricating oil pressure; however, steam is to be made available at the astern turbine for braking purposes in such an emergency. *See Vol 2, Pt 7, Ch 3 Machinery Piping Systems* for emergency oil supply.

5.1.2 Auxiliary turbine arrangements are to be such that steam supply is automatically shut off in the event of failure of the lubricating oil pressure.

5.2 Single screw ships

5.2.1 In single screw ships fitted with cross compound steam turbine installations in which two or more turbines are separately coupled to the same main gear wheel, the arrangements are to be such as to enable safe navigation when the steam supply can be led direct to the L.P. turbine and either the H.P or I.P. turbine can exhaust direct to the condenser. Adequate arrangements and controls are to be provided for these emergency operating conditions so that the pressure and temperature of the steam will not exceed those which the turbines and condenser can safely withstand.

5.2.2 The necessary pipes and valves or fittings for these arrangements are to be readily available and properly marked. A fit up test of all combinations of pipes and valves is to be performed prior to the first sea trials.

5.2.3 The permissible power/speeds of the operating turbines(s) when operating without one of the turbines (all combinations) is to be specified and information provided on board.

5.2.4 The operation of the turbines under emergency conditions is to be assessed for the potential influence on shaft alignment and gear teeth loading conditions.

5.3 Single main boiler

5.3.1 Ships intended for unrestricted service, fitted with steam turbines and having a single main boiler, are to be provided with means to ensure emergency propulsion in the event of failure of the main boiler.

■ Section 6
Piping systems

6.1 General

6.1.1 Steam turbine piping systems are, in general, to comply with the requirements given in *Vol 2, Pt 7, Ch 1 Piping Design Requirements* and *Vol 2, Pt 7, Ch 3 Machinery Piping Systems*, due regard being paid to the particular type of installation.

6.1.2 Synthetic rubber hoses, with single or double closely woven integral wire braid reinforcement, or convoluted metal pipes with wire braid protection, may be used in condensate and lubricating oil systems. *see also Vol 2, Pt 7, Ch 1 Piping Design Requirements*.

6.2 Lubricating oil systems

6.2.1 Lubricating oil arrangements are to comply with the requirements of *Vol 2, Pt 7, Ch 3 Machinery Piping Systems*.

6.2.2 Where the lubricating oil for main propelling steam turbines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the turbine or reducing the supply of filtered oil to the turbine.

6.3 Cooling systems

6.3.1 Cooling water arrangements are to comply with the requirements of *Vol 2, Pt 7, Ch 3 Machinery Piping Systems*, as applicable.

6.4 Bled steam connections

6.4.1 Non-return or other means, which will prevent steam and water returning to the turbines, are to be fitted in bled steam connections.

6.5 Steam strainers

6.5.1 Efficient steam strainers are to be provided close to the inlets to ahead and astern high pressure turbines, or alternatively at the inlets to the manoeuvring valves.

■ Section 7
Control and monitoring

7.1 General

7.1.1 Control engineering systems are, in general, to comply with the requirements of *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*.

7.2 Overspeed protective devices

7.2.1 An overspeed protective device is to be provided for main and auxiliary turbines to shut off the steam automatically and prevent the maximum designed speed being exceeded by more than 15 per cent.

7.2.2 Where two or more turbines of a compound main turbine installation are separately coupled to the same main gear wheel, and one overspeed protective device is provided, this is to be fitted to the L.P. ahead turbine. Hand trip gear for shutting off the steam in an emergency is to be provided at the manoeuvring platform.

7.3 Speed governors

7.3.1 Where a turbine installation incorporates a reverse gear, electric transmission or reversible propeller, a speed governor in addition to, or in combination with, the overspeed protective device is to be fitted, and is to be capable of controlling the speed of the unloaded turbine without bringing the overspeed protective device into action.

7.3.2 Auxiliary turbines intended for driving electric generators are to be fitted with speed governors which, with fixed setting, are to control the speed within 10 per cent momentary variation and 5 per cent permanent variation when full load is suddenly taken off or put on. The permanent speed variations of alternating current machines intended for parallel operations are to equalise within a tolerance of ± 0,5 per cent.

7.4 Low vacuum and overpressure warning devices

7.4.1 To provide a warning of excessive pressure to personnel in the vicinity of turbine exhaust ends, sentinel relief valves are to be provided at the exhaust ends or other approved positions of all main turbines, and the valve discharge outlets are to be visible and suitably guarded if necessary. Where a low vacuum cut-out device is provided, the sentinel relief valve at the L.P. exhaust may be omitted.

7.4.2 To provide a warning of excessive pressure to personnel in the vicinity of turbine exhaust ends, sentinel relief valves are to be provided at exhaust ends of all auxiliary turbines and the valve discharge outlets are to be visible and suitably guarded if necessary. Low vacuum or overpressure cut-out devices, as appropriate, also to be provided for auxiliary turbines not installed with their own condensers.

7.5 Steam turbines for propulsion purposes

7.5.1 Where steam turbines for propulsion purposes are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by operators, they are to be provided with the alarm and safety arrangements required by *Vol 2, Pt 2, Ch 3, 7.5 Steam turbines for propulsion purposes 7.5.2* to *Vol 2, Pt 2, Ch 3, 7.5 Steam turbines for propulsion purposes 7.5.7* and *Table 3.7.1 Steam turbine machinery: Alarms and safeguards* as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

Table 3.7.1 Steam turbine machinery: Alarms and safeguards

Item	Alarm	Note
Lubricating oil pressure for turbines and gearing	1st stage Low	—
Lubricating oil pressure for turbines and gearing	2nd stage Low	Automatic shutdown *see Vol 2, Pt 2, Ch 3, 7.5 Steam turbines for propulsion purposes 7.5.2*
Lubricating oil temperature for turbines and gearing	High	—
Lubricating oil sump level	Low	—
Lubricating oil filters differential pressure	High	—
Bearing temperatures or bearing oil outlet temperature of turbines and gearing	High	—
Astern turbine temperature	High	—
Gland steam pressure	High and low	—
Thrust bearing temperature	High	—
Sea-water pressure or flow	Low	—
Turbine vibration	High	Shutdown or speed reduction of turbine(s)
Axial movement of turbine rotor	High	Shutdown or speed reduction of turbine(s)
Main condenser vacuum	Low	Shutdown or speed reduction of turbine(s)
Main condenser condensate level	High	Shutdown or speed reduction of turbine(s)
Overspeed	High	*See Vol 2, Pt 2, Ch 3, 7.2 Overspeed protective devices*

7.5.2 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery are required by *Table 3.7.1 Steam turbine machinery: Alarms and safeguards* and *Table 3.7.2 Steam turbine machinery: Additional alarms and safeguards*, the sensors and circuits utilised for the second stage alarm and automatic shutdown are to be independent of those required for the first stage alarm.

7.5.3 Audible and visual alarms are to operate, and indication is to be given at the relevant control stations to stop or reduce the speed of the turbine(s) for the following fault conditions:

(a) Excessive turbine vibration.
(b) Excessive axial movement of turbine rotor.
(c) Low vacuum in main condenser.
(d) High condensate level in main condenser.

Table 3.7.2 Steam turbine machinery: Additional alarms and safeguards

Item	Alarm	Note
Lubricating oil inlet temperature	High	—
Lubricating oil inlet pressure	1st stage Low	—
Lubricating oil inlet pressure	2nd stage* Low	Automatic shutdown of turbine*, *see Vol 2, Pt 2, Ch 3, 7.5 Steam turbines for propulsion purposes 7.5.2*
Condenser vacuum	Low	Automatic shutdown of turbine*
Axial displacement of rotor	High	Automatic shutdown of turbine*

Overspeed	High	*See Vol 2, Pt 2, Ch 3, 7.2 Overspeed protective devices*
Note There are no classification requirements for the items marked * in the case of engines being used for the emergency source of electrical power. **Note** The tailoring document or System Design Description may specify additional requirements of the Naval Administration.		

7.5.4 Reduction of speed may be effected by either manual or automatic control.

7.5.5 Means are to be provided to prevent the risk of thermal distortion of the turbines, by automatic steam spinning, when the shaft is stopped in the manoeuvring mode. An audible and visual alarm is to be provided at the relevant control stations when the shaft has been stopped for a predetermined time.

7.5.6 The following turbine services are to be fitted with automatic controls so as to maintain steady state conditions throughout the normal operating range of the propulsion turbine(s):

(a) Lubricating oil supply temperature.
(b) Condenser condensate level.
(c) Gland steam pressure.

7.5.7 Prolonged running in a restricted speed range is to be prevented automatically or, alternatively, indication of restricted speed ranges is to be provided at each control station.

7.6 Steam turbines for auxiliary purposes

7.6.1 Where steam turbines for auxiliary purposes are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by operators, they are to be provided with the alarm and safety arrangements required by *Table 3.7.2 Steam turbine machinery: Additional alarms and safeguards* as appropriate. Alternative arrangements which provide equivalent safeguards will be considered.

Section

■ *Section 1* Scope

1.1 Application

1.1.1 This Chapter, defines the requirements for the design and service life of marine gears and is to be read in conjunction with the General Requirements for Machinery and Engineering Systems in *Vol 2, Pt 1, Ch 1 General Requirements for Classification of Engineering Systems* and *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*.

1.1.2 The scope of this Chapter includes gearing for main propulsion and auxiliary machinery, the support arrangements, the controls and systems necessary to maintain operation and functionality of the unit. The contents are in respect of mechanical integrity of the gears, control and monitoring systems and other support critical systems.

1.1.3 Marine gears utilised for propulsion or electrical power generation purposes are within the Mobility and Ship Type categories as defined in *Vol 2, Pt 1, Ch 1, 3 Engineering system designation*

1.1.4 The requirements of this Chapter are applicable to electric motor, gas turbine, steam turbines and diesel engine gearing for driving:

(a) Conventional, totally submerged propeller(s)/impeller(s) for main propulsion purposes where the transmitted powers exceed 220 kW.

(b) Auxiliary machinery that is essential for the safety of the ship or for the safety of persons on board where the transmitted powers exceed 110 kW.

1.1.5 Gear designs for applications other than those specified in *Vol 2, Pt 3, Ch 1, 1.1 Application 1.1.4* will be specially considered.

1.1.6 In any mesh, the terms pinion and wheel refer to the smaller and larger gear respectively.

1.1.7 Bevel gears will be specially considered on the basis of a conversion to equivalent cylindrical gears.

1.1.8 Gear type testing will be required as part of the approval process for first of type.

1.1.9 *See Vol 2, Pt 1, Ch 3, 10 Gearing* for construction, installation and testing requirements.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of any particular components are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in *Vol 2, Pt 1, Ch 3, 4.3 Power ratings*

Section 2
Principles

2.1 Design and operating principles

2.1.1 Marine gears are to be designed in accordance with user defined operating and performance criteria, taking account of ship type and service operating envelope.

2.1.2 Marine gears are to be capable of continuous operation between the maximum and minimum output power at specified operating conditions, *see Vol 2, Pt 1, Ch 3, 4 Operating conditions*.

2.1.3 Marine gears are to be designed and installed such that degradation or failure of any other independent system will not render the gears inoperable.

2.1.4 Marine gears necessary for propulsion or steering of the ship are to be designed and installed such that power transmission can be maintained in the event of single failure in an operational sub-system.

2.1.5 The gearing installation is to be capable of operating for the service profile throughout the specified life of the ship.

2.2 Lifecycle principles

2.2.1 Gears are to be operated and maintained such that the required performance, integrity and reliability can be achieved throughout the life of the ship.

2.2.2 To demonstrate continued compliance with the classification provisions for engineering systems (*see Vol 2, Pt 1, Ch 1, 2.1 Provisions 2.1.1*), surveys are to be carried out in accordance with the Regulations.

2.3 Enhanced analysis principles

2.3.1 Where the design of gearing has used enhanced analysis methods as described in *Vol 2, Pt 3, Ch 1, 2.3 Enhanced analysis principles 2.3.2* to *Vol 2, Pt 3, Ch 1, 2.3 Enhanced analysis principles 2.3.5*, the ship will be eligible for the optional machinery class notation **AG1** or **AG2** as applicable. These optional class notations may be applied where the Owner requires detailed knowledge of the reliability of the gear elements and where noise excitation is required to be minimised for anticipated service conditions. Eligibility for the **AG1** class notation will be subject to analysis in accordance with ISO 6336 and the use of an acceptable validated analytical meshing model for determining the face load factor for contact stress $K_{H\beta}$ by direct calculations. The analytical mesh model is to include consideration of the following:

(a) Phase varying lines of contact at the mesh.
(b) Elastic deflection of the gears, supporting shafts and other supporting components.
(c) Geometric qualities of any helix and profile modifications.
(d) Manufacturing tolerances.

2.3.2 Where, in addition to the requirements for **AG1** class notation, a validated three dimensional finite element program is used for determining the flexibility of the geometry of mating gears, the ship will be eligible for **AG2** class notation.

2.3.3 Gear elements are to be analysed using ISO 6336 with the following additions:

(a) The face load factor for contact stress (K_{Hmesh}) is to be calculated using an acceptable validated analytical meshing model and used in place of the equivalent factor ($K_{H\beta}$ x $K_{H\alpha}$) given in ISO 6336. The actual factor of safety against surface failure is effectively adjusted as follows:

$$S_{\mathrm{H}} = S_{\mathrm{HISO}}\sqrt{\frac{K_{\mathrm{H}\,\beta} . K_{\mathrm{H}\,\alpha}}{K_{\mathrm{Hmesh}}}}\ (\mathrm{toexceed}1,4)$$

(b) The face load factor for bending stress (K_{Fmesh}) is to be calculated in accordance with ISO 6336 using the K_{Hmesh} value calculated from the validated analytical mesh model. The actual factor of safety against surface failure is effectively adjusted as follows:

$$S_{\mathrm{F}} = S_{\mathrm{F_{ISO}}}\frac{K_{\mathrm{F}\,\beta} K_{\mathrm{F}\,\alpha}}{K_{\mathrm{H_{Mesh}}}}\ (\mathrm{toexceed}1,8)$$

The factors of safety derived from the stress analysis procedure are only to be used for comparing the gears of similar design.

2.3.4 The ability of gearing to operate without scuffing at loads up to and including the maximum specified transient overload is to be demonstrated using at least two different methods. The assessment is to take full account of predicted transverse load distribution.

2.3.5 The design of the gearing is to be capable of accepting the following overload conditions as applicable and the over-speed without risk of damage:

(a) A non-transient ahead torque overload (duration of more than three seconds) of 125 per cent maximum full power torque in steam turbine and diesel installations, and of 150 per cent maximum full power torque in gas turbine installations. Torque levels up to these may occur during high power turns and rapid accelerations up to a total of five hours during a ship's life. Gears and shafts are to be capable of withstanding 200 per cent of full power statically as could occur if for instance the propeller becomes jammed.
(b) Over-speed of 15 per cent above the specified input speed.

■ *Section 3* Acceptance criteria

3.1 General

3.1.1 Conformance with the performance criteria, together with any specific requirements of the applicable Rules, standards and legislation is to be demonstrated by the gear manufacturer, shipbuilder and Owner to the satisfaction of Lloyd's Register (hereinafter referred to as 'LR).

3.1.2 For gears, the applicable Rules and Standards for classification are:

(a) LR Rules for the Classification of Naval Ships.
(b) ISO 6336 Parts 1, 2, 3 and 5.
(c) ISO 1328 – *Parallel involute gears ISO System of Accuracy.*
(d) ISO 1940 – *Balancing.*
(e) Requirements of the Naval Administration as specified.
(f) Other specific Owner requirements. These are to be identified before commencement of design review or construction.
(g) LR Type Approval System.
(h) LR Quality Scheme for Machinery.

■ *Section 4* Design and construction

4.1 General

4.1.1 Documents relevant to the design, construction, installation, testing and operation of gears are:

(a) LR's Rules for Gearing, *see* Sections 5 to 9 and *Vol 2, Pt 1, Ch 3, 10 Gearing*
(b) The gearing manufacturer's recommendations.

4.1.2 The overall performance of gears installed in ships is to be demonstrated to conform with the performance criteria specified. If necessary, tests may be carried out in conjunction with the ship's operational pattern.

Section 5
Documentation required for design review

5.1 Plans

5.1.1 Particulars of the gearing are to be submitted with the plans, in triplicate, for all propulsion gears and for auxiliary gears where the transmitted power exceeds 110 kW.

5.2 Shafts and sub-systems

5.2.1 Plans showing details of shafts, bearings (position and type), couplings and any clutches are to be submitted.

5.2.2 Schematic plans of the lubricating oil system, together with pipe material, relief valve and working pressures are to be submitted.

5.2.3 Schematic plans showing arrangements of the gearbox dehumidification arrangements are to be submitted.

5.2.4 Schematic plans showing arrangements of the control, safety and electrical systems are to be submitted.

5.3 Design data and calculations

5.3.1 A System Design Description for the gearing installation, *see Vol 2, Pt 1, Ch 3, 3.5 System design description*.

5.3.2 A Risk Assessment (RA) as required by *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems* is to be submitted. The RA is to be carried out in accordance with the requirements of *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)* and is to include the following associated sub-systems:

- Clutches.
- Flexible couplings.
- Lubricating oil.
- Cooling arrangements.
- Dehumidification.
- Gearbox mounting.
- Control and monitoring.
- Electrical power supplies.

It is not necessary to consider failure modes relating to the gearbox components.

5.3.3 Details of calculations and tests to establish the service life of safety critical components, including couplings, gearing (where applicable), bearings and seals are to be submitted.

5.3.4 A technical file with bearing particulars, sizes, position of oil inlets, diametral clearances and lubricating oil arrangements are to be submitted.

5.3.5 Calculations demonstrating compliance with requirements for class notations **AG1** and **AG2** are to be submitted where applicable.

5.3.6 Details of the turning gear and its operational limitations are to be provided.

Section 6
Materials

6.1 General

6.1.1 In the selection of materials for pinions and wheels, consideration is to be given to their compatibility in operation. Except in the case of low reduction ratios, for gears of through-hardened steels, provision is to be made for a hardness differential between pinion teeth and wheel teeth. For this purpose, the specified minimum tensile strength of the wheel rim material is not to be more than 85 per cent of that of the pinion.

6.1.2 Subject to *Vol 2, Pt 3, Ch 1, 6.1 General 6.1.1*, the specified minimum tensile strength is to be selected within the following limits:

(a) Pinion and pinion sleeves: 550 to 1050 N/mm^2.
(b) Gear wheels and rims: 400 to 850 N/mm^2.

A tensile strength range is also to be specified and is not to exceed 120 N/mm^2 when the specified minimum tensile strength is 600 N/mm^2 or less. For higher strength steels, the range is not to exceed 150 N/mm^2.

6.1.3 Unless otherwise agreed by LR, the specified minimum tensile strength of the core is to be 800 N/mm^2 for induction-hardened or nitrided gearing and 750 N/mm^2 for carburised gearing.

6.1.4 For nitrided gearing, the full depth of the hardened zone is to be not less than 0,5 mm and the hardness is to be not less than 500 HV for a depth of 0,25 mm.

6.2 Material specifications

6.2.1 Specifications for materials of pinions, pinion sleeves, wheel rims, gear wheels, and quill shafts, giving chemical composition, heat treatment and mechanical properties, are to be submitted for approval with the plans of gearing.

6.2.2 Where the teeth of a pinion or gear wheel are to be surface hardened, i.e,. carburised, nitrided, tufftrided or induction-hardened, the proposed specification and details of the procedure are to be submitted for approval.

■ *Section 7* Design

7.1 General

7.1.1 Gears are to be designed to ISO 6336 Method B, or equivalent, and are to comply with the requirements of this Chapter.

7.1.2 It is the manufacturer's responsibility to provide, together with the requirements of *Vol 2, Pt 3, Ch 1, 5.1 Plans 5.1.1*, results of the calculations with all relevant input data.

7.2 Fatigue limits

7.2.1 Acceptable limiting fatigue bending stresses for various materials are given in *Table 1.7.1 Values of endurance limit for bending stress, $\sigma_{F\,lim}$*, where σ_B is the ultimate tensile strength, in N/mm^2, and HV is the Vickers hardness number.

Table 1.7.1 Values of endurance limit for bending stress, $\sigma_{F\,lim}$

Heat treatment	$\sigma_{F\,lim}$ N/mm^2
Through-hardened carbon steel	$0{,}09\sigma_B + 150$
Through-hardened alloy steel	$0{,}1\sigma_B + 185$
Soft bath nitrided (tuffrided)	330
Induction hardened	$0{,}35HV + 125$
Gas nitrided	390
Carburised A	450
Carburised B	410
Note 1. A is applicable for CR Ni Mo carburising steels.	
Note 2. B is applicable for other carburising steels.	

7.2.2 Acceptable limiting fatigue surface stresses for various surface treatments are given in *Table 1.7.2 Values of endurance limit for Hertzian contact stress, $\sigma_{H\,lim}$*. Material mechanical properties are based on the gear wheel values.

Table 1.7.2 Values of endurance limit for Hertzian contact stress, $\sigma_{H\ lim}$

Heat treatment		$\sigma_{H\ lim}$ N/mm^2
Pinion	Wheel	
Through-hardened	Through-hardened	$0,46\sigma_{B2} + 255$
Surface hardened	Through-hardened	$0,46\sigma_{B2} + 415$
Carburised, nitrided or induction-hardened	Soft bath nitrided (tufftrided)	1000
Carburised, nitrided or induction-hardened	Induction-hardened	$0,88HV_2 + 675$
Carburised or nitrided	Nitrided	1300
Carburised	Carburised	1500

7.3 Tooth form

7.3.1 The fundamental tooth profile in the transverse section is to be of involute shape, and the roots of the teeth are to be formed with smooth fillets of radii not less than 0,25 of gear normal modulus (mn).

7.4 Tooth loading factors

7.4.1 For values of application factor, K_A, *see Table 1.7.3 Values of* K_A .

Table 1.7.3 Values of K_A

Main and auxiliary gears	K_A
Main propulsion – electric motor or gas turbine, reduction gears	1,15
Main propulsion – diesel engine reduction gears:	
Hydraulic coupling or equivalent on input	1,10
High elastic coupling on input	1,30
Other coupling	1,50
Auxiliary Gears:	
Electric, gas turbine and diesel engine drives with hydraulic coupling or equivalent on input	1,00
Diesel engine drives with high elastic coupling on input	1,20
Diesel engine drives with other couplings	1,40

7.4.2 Load sharing factor, K_g. The value for K_g is to be taken as 1,15 for multi-engine drives or split torque arrangements. Otherwise, K_g is to be taken as 1,0. Alternatively, where measured data exists, a derived value will be considered.

7.5 Factors of safety

7.5.1 The required factors of safety are shown in *Table 1.7.4 Factors of safety*, where $S_{H\ min}$ relates to surface stress and $S_{F\ min}$ to bending stress.

Table 1.7.4 Factors of safety

	$S_{H\ min}$	$S_{F\ min}$
Main propulsion gears	1,40	1,80
Auxiliary gears	1,15	1,40

7.6 Gear wheels

7.6.1 In general, arrangements are to be made so that the interior structure of the wheel may be examined. Alternative proposals will be specially considered.

7.7 Clutch actuation

7.7.1 Where a clutch is fitted in the transmission, normal engagement shall not cause excessive stresses in the transmission or the driven machinery. Inadvertent operation of any clutch is not to produce dangerously high stresses in the transmission or driven machinery.

7.8 Gearcases

7.8.1 Gearcases and their supports are to be designed to be sufficiently stiff such that movements of the external foundations and the thermal effects under all conditions of service do not disturb the tooth contact.

7.8.2 Inspection openings are to be provided at the peripheries of gearcases to enable the teeth of pinions and wheels to be readily examined. Where the construction of gearcases is such that sections of the structure cannot readily be moved for inspection purposes, access openings of adequate size are also to be provided at the ends of the gearcases to permit examination of the structure of the wheels. The attachment to the shafts is to be capable of being examined by removal of bearing caps or by equivalent means.

7.8.3 Access arrangements for examination and maintenance are to be provided for internal clutches, brakes, bearings and couplings where applicable.

7.8.4 Electrical equipment fitted within the gear case is to be suitable for installation in an oil-laden atmosphere and consideration is to be given to areas where oil sprays play directly onto electrotechnical equipment and/or cable fastenings. All electrical items are to be earthed to meet the requirements of *Vol 2, Pt 9 Electrotechnical Systems*. Gearcases are to be earthed to the ship's structure.

7.8.5 For gearcase security arrangements, *see Vol 2, Pt 7, Ch 3, 8.14 Security 8.14.2*

7.9 Alignment

7.9.1 Reduction gears with sleeve bearings are to be provided with means for checking the internal alignment of the various elements in the gearcases.

7.9.2 In the case of separately mounted reduction gearing for main propulsion means are to be provided by the gear manufacturer to enable the Surveyors to verify that no distortion of the gearcase has taken place, when chocked and secured to its seating on board ship.

7.9.3 *See Vol 2, Pt 5, Ch 4 Shaft Alignment* for further requirements.

7.10 Turning gear

7.10.1 The gearbox is to be provided with a means of turning the gearing for inspection and maintenance purposes. The turning gear is to be designed to turn the shaft at a rate to allow visual inspection without risk to bearings when the oil supply is off. The turning gear arrangements are to provide means that enable ready operation by hand.

■ Section 8
Sub-systems for gearing

8.1 General

8.1.1 The lubricating oil distribution system for gears and bearings is to comply with the gear manufacturer's requirements and recommendations.

8.1.2 Piping systems for gearing are to comply with the general design requirements in *Vol 2, Pt 7, Ch 3 Machinery Piping Systems*. Specific requirements for lubricating/hydraulic oil systems and standby arrangements are also stated in *Vol 2, Pt 7, Ch 3 Machinery Piping Systems*

8.1.3 Lubricating oil lines are to be screened, or otherwise suitably protected, to avoid oil spray or oil leakage onto hot surfaces, into machinery air intakes or other sources of ignition. The number of joints in such piping systems is to be kept to a minimum. Flexible pipes are to be of approved type.

8.2 Pumps

8.2.1 Where lubricating oil for gearing is circulated under pressure, pump standby arrangements are to be provided in accordance with *Vol 2, Pt 7, Ch 3 Machinery Piping Systems*.

8.3 Filters

8.3.1 Where lubricating oil for gearing is circulated under pressure, provision is to be made for efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the gears or reducing the supply of filtered oil to the gearing.

8.4 Gearbox dehumidification

8.4.1 All gearboxes installed in **NS1** and **NS2** category ships are to be fitted with a dehumidifier to remove moist air from the gearcase during periods of shutdown.

8.4.2 The dry air produced by the dehumidifier is to have a relative humidity of no more than 30 per cent at 15°C.

■ Section 9
Control and monitoring

9.1 General

9.1.1 Control engineering systems are to be in accordance with *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*

9.1.2 All main and auxiliary gear units, intended for Mobility and/or Ship Type systems, are to be provided with means of indicating the lubricating oil supply pressure. Audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. These alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

9.2 Unattended machinery

9.2.1 Where the machinery is fitted with automatic or remote controls so that under normal operating conditions it does not require any manual intervention by the operators, gear units are to be provided with alarms and safety arrangements required by *Vol 2, Pt 3, Ch 1, 9.2 Unattended machinery 9.2.2* and *Table 1.9.1 Alarms and safeguards*. The sensors and circuits utilised for the second stage alarm and automatic shutdown in *Table 1.9.1 Alarms and safeguards* are to be independent of those required for the first stage alarm.

Table 1.9.1 Alarms and safeguards

Item	Alarm	Note
Lubricating oil sump level	Low	–
Lubricating oil inlet pressure*	1st Stage Low	Slow-down of prime mover
Lubricating oil inlet pressure*	2nd Stage Low	Automatic shutdown of prime mover
Lubricating oil inlet temperature*	High	–
Thrust bearing temperature*	High	Slow-down of prime mover
Note Where the prime mover is an electric motor then this is to be fitted with a means of reducing speed to enable compliance with this Table. Where gearboxes use an external oil tank for the lubricating oil supply then this is to be considered as the sump.		

9.2.2 Where the gear unit is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pump falls below a predetermined value.

■ *Scope*

The requirements of this Chapter relate, in particular, to formulae for determining the diameters of shafting for main propulsion installations, but requirements for couplings, coupling bolts, keys, keyways, sternbushes and other associated components are also included. The diameters may require to be modified as a result of alignment considerations and vibration characteristics, *see Vol 2, Pt 5 Shaft Vibration and Alignment*, or the inclusion of stress raisers, other than those contained in this Chapter.

Alternative calculation methods for determining the diameters of shafting for main propulsion and their permissible torsional stresses will be considered by LR. Any alternative calculation method is to include all relevant loads on the complete dynamic shafting system under all permissible operating conditions. Consideration is to be given to the dimensions and arrangements of all shaft connections. Moreover, an alternative calculation method is to take into account design criteria for continuous and transient operating loads (dimensioning for fatigue strength) and for peak operating loads (dimensioning for yield strength). The fatigue strength analysis may be carried out separately for different load assumptions, for example as given below.

Shafts complying with the applicable Rules in this Chapter and *Vol 2, Pt 5 Shaft Vibration and Alignment* satisfy the following:

(a) Low cycle fatigue criterion (typically $<10^4$), i.e. the primary cycles represented by zero to full load and back to zero, including reversing torque if applicable. This is addressed by the formulas in *Vol 2, Pt 3, Ch 2, 4.2 Intermediate shafts*, *Vol 2, Pt 3, Ch 2, 4.4 Screwshafts and tube shafts* and *Vol 2, Pt 3, Ch 2, 4.5 Hollow shafts*
(b) High cycle fatigue criterion (typically $>>10^7$), i.e. torsional vibration stresses permitted for continuous operation as well as reverse bending stresses and the accumulated fatigue due to torsional vibration when passing through a barred speed range or any other transient condition with associated stresses beyond those permitted for continuous operation. This is addressed by the formulas in *Vol 2, Pt 5, Ch 1, 3.2 Limiting stress in propulsion shafting*. The influence of reverse bending stresses is addressed by the safety margins inherent in the formulas in *Vol 2, Pt 3, Ch 2, 4.2 Intermediate shafts*, *Vol 2, Pt 3, Ch 2, 4.4 Screwshafts and tube shafts* and *Vol 2, Pt 3, Ch 2, 4.5 Hollow shafts*.

■ *Section 1*
General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the General requirements for Machinery and Engineering Systems in *Vol 2, Pt 1, Ch 1 General Requirements for Classification of Engineering Systems* and *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*.

1.1.2 For shafting enclosed within a gearbox, *see Vol 2, Pt 3, Ch 1, 7 Design*

1.1.3 For diesel engine crankshaft and turbine rotor shafting, *see Vol 2, Pt 2, Ch 1 Reciprocating Internal Combustion Engines Vol 2, Pt 2, Ch 2 Gas Turbines* and *Vol 2, Pt 2, Ch 3 Steam Turbines*.

1.2 Power ratings

1.2.1 In this Chapter the dimensions of main propulsion component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*. The values used are those defined in *Vol 2, Pt 1, Ch 3, 4.3 Power ratings*

1.2.2 For auxiliary machinery, the maximum continuous shaft power and corresponding revolutions per minute which will be used in service are to be stated.

1.3 Clutches

1.3.1 Clutches for single engine propulsion plants are to be provided with a suitable means for emergency operation in the event of loss of operating fluid systems. Their suitability for short term high power operation is to be demonstrated.

1.4 Safety

1.4.1 Means are to be provided such that in the event of a failure to a shaft or coupling the occupants of the ship are not endangered, either directly or by damaging the ship or its systems. Where necessary, guards may be fitted to achieve compliance with these requirements.

■ *Section 2* Documentation required for design review

2.1 Documentation

2.1.1 At least three copies of the following plans are to be submitted:

- Shafting arrangement.
- Thrust shaft.
- Intermediate shafting.
- Tube shaft, where applicable.
- Screwshaft.
- Shaft bearings fitted in sternbushes and shaft bossings in ‘A’ and ‘P’ brackets.
- Screwshaft oil gland.
- Screwshaft protection.
- Sternbush and arrangement in housing.
- Couplings.
- Coupling bolts.
- Flexible coupling.
- Cardan shafts.

2.1.2 The shafting arrangement plan is to indicate the relative position of the main engine(s), flywheel, flexible coupling(s), gearing, thrust block, line shafting and bearing(s), sterntube, ‘A’ bracket and propulsion device, as applicable.

2.1.3 A Risk Assessment (RA) as required by *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems* is to be submitted. The RA is to be carried out in accordance with the requirements of *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)* and is to include the following associated sub-systems:

- Clutches.
- Flexible couplings.
- Lubrication.
- Cooling arrangements.
- Bearing mountings.
- Control and monitoring.
- Electrical power supplies.
- Thrust blocks.

It is not necessary to consider failure modes relating to the shafting components.

2.2 Calculations and specifications

2.2.1 The following calculations and specifications are to be submitted:

- Calculations, or relevant documentation indicating the suitability of all components for short term high power operation, where applicable.
- Where undertaken as an alternative to the requirements to this Chapter, fatigue endurance calculations of all components according to *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*
- Vibration analysis and alignment analysis as required by *Vol 2, Pt 5 Shaft Vibration and Alignment*
- The material specifications, including the minimum specified tensile strength of each shaft and coupling component is to be stated. Where corrosion resistant material not included in *Table 2.4.1 Provisional 'A' value for use in unprotected screwshaft formula* is used for unprotected screwshafts, the corrosion fatigue strength in sea-water is to be stated together with the chemical composition and mechanical properties.
- Where it is proposed to use composite (non-metallic) shafts, details of materials, resin, lay-up procedure and documentary evidence of fatigue endurance strength.
- For water lubricated bearings in sternbushes and sterntubes, details of the piping system and means for verifying that the required water flow specified by the bearing manufacturers is being maintained. *See also Vol 2, Pt 3, Ch 2, 4.16 Sternbushes and sterntube arrangements*.

■ *Section 3*
Materials

3.1 Materials for shafts

3.1.1 Components are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

3.1.2 The specified minimum tensile strength of forgings for shafts is to be selected within the following general limits:

(a) Carbon and carbon-manganese steel – 400 to 760 N/mm^2 (41 to 77,5 kgf/mm^2). *See also Vol 2, Pt 3, Ch 2, 4.4 Screwshafts and tube shafts 4.4.1*.

(b) Alloy steel – not exceeding 800 N/mm^2 (82 kgf/mm^2) and for other forgings not exceeding 1100 N/mm^2.

3.1.3 Where it is proposed to use alloy steel, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

3.1.4 Where shafts may experience vibratory stresses close to the permissible stresses for transient operation, the materials are to have a specified minimum tensile strength of 500 N/mm^2 (51 kgf/mm^2).

3.1.5 Where materials with greater specified or actual tensile strengths than the limitations given above are used, reduced shaft dimensions or higher permissible vibration stresses are not acceptable when derived from the formulae used in *Vol 2, Pt 3, Ch 2, 4.2 Intermediate shafts*, *Vol 2, Pt 3, Ch 2, 4.4 Screwshafts and tube shafts* and *Vol 2, Pt 5, Ch 1, 3.2 Limiting stress in propulsion shafting*.

3.1.6 Unprotected screwshafts and tubeshafts exposed to sea-water are, in general, to be manufactured from corrosion resistant ferrous or non-ferrous material, such as those indicated in *Table 2.4.1 Provisional 'A' value for use in unprotected screwshaft formula*

3.1.7 In the selection of materials for shafts, keys, locking nuts etc. consideration is to be given to their compatibility with the proposed propeller material.

3.1.8 Where shafts are manufactured from composite material the process is to be approved.

3.2 Shaft bearing materials

3.2.1 Shaft bearings fitted in sternbushes and shaft bossings in ‘A’ and ‘P’ brackets are to be constructed from an approved material and effectively secured to prevent rotational and axial movement in the sterntube(s) and sternbush(es).

Section 4
Design and construction

4.1 Fatigue strength analysis

4.1.1 As an alternative to the following requirements, a fatigue strength analysis of components can be submitted indicating a factor of safety of 1,5 at the design loads, based on suitable fatigue failure criteria. The effects of stress concentrations, material properties and operating environment are to be taken into account.

4.2 Intermediate shafts

4.2.1 The diameter, *d*, of the intermediate shaft is to be not less than that determined by the following formula:

$$d = Fk\sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)}\ \text{mm}$$

where

k = 1,0 for shafts with integral coupling flanges complying with *Vol 2, Pt 3, Ch 2, 4.8 Flange connections of couplings* or with shrink fit couplings, *see Vol 2, Pt 3, Ch 2, 4.2 Intermediate shafts 4.2.4*

= 1,10 for shafts with keyways, in tapered or cylindrical connections, where the fillet radii in the transverse section of the bottom of the keyway are not less than 0,0125*d*, *see Vol 2, Pt 3, Ch 2, 4.2 Intermediate shafts 4.2.5*

= 1,10 for shafts with transverse or radial holes where the diameter of the hole (d_h) does not exceed 0,3*d*

= 1,20 for shafts with longitudinal slots *see Vol 2, Pt 3, Ch 2, 4.2 Intermediate shafts 4.2.6*.

F = 95 for turbine installations, electric propulsion installations and diesel engine installations with slip type couplings

= 100 (90,5) for other diesel engine installations

P and *R* are defined in *Vol 2, Pt 1, Ch 3, 4.3 Power ratings 4.3.1* (losses in gearboxes and bearings are to be disregarded)

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2(kgf/mm^2), *see Vol 2, Pt 3, Ch 2, 3.1 Materials for shafts 3.1.2*.

4.2.2 Beyond a length of 0,2*d* from the end of a keyway, transverse hole or radial hole and 0,3*d* from the end of a longitudinal slot, the diameter of the shaft may be gradually reduced to that determined with k = 1,0.

4.2.3 For shafts with design features other than stated as above, the value of *k* will be specially considered.

4.2.4 For shrink fit couplings, *k* refers to the plain shaft section only. Where shafts may experience vibratory stresses close to the permissible stresses for continuous operation, an increase in diameter to the shrink fit diameter is to be provided, e.g. a diameter increase of 1 to 2 per cent and a blending radius as described in *Vol 2, Pt 3, Ch 2, 4.8 Flange connections of couplings*.

4.2.5 Keyways are in general not to be used in installations with a barred speed range.

4.2.6 The application of *k* = 1,20 is limited to shafts with longitudinal slots having a length of not more than 0,8*d* and a width of not more than 0,1*d* and a diameter of central hole d_i of not more than 0,8*d*, *see Vol 2, Pt 3, Ch 2, 4.5 Hollow shafts*. The end rounding of the slot is not to be less than half the width. An edge rounding should preferably be avoided as this increases the stress concentration slightly. The values of c_K, *see Table 1.3.1 Ck factors* in Pt 5, Ch 1, are valid for 1, 2 and 3 slots, i.e. with slots at 360, 180 and 120 degrees apart respectively.

4.3 Thrust shafts external to engines

4.3.1 The diameter at the collars of the thrust shaft transmitting torque or in way of the axial bearing where a roller bearing is used as a thrust bearing, is to be not less than that required for the intermediate shaft in accordance with *Vol 2, Pt 3, Ch 2, 4.2 Intermediate shafts* with a *k* value of 1,10. Beyond a length equal to the thrust shaft diameter from the collars, the diameter may be

tapered down to that required for the intermediate shaft with a *k* value of 1,0. For the purpose of the foregoing calculations, σ_u is to be taken as the minimum tensile strength of the thrust shaft material, in N/mm^2. The fillet radius at the base of both sides of the thrust collar is to be not less than 0,08 of the diameter of the shaft at the collar.

4.4 Screwshafts and tube shafts

4.4.1 Screwshafts and tube shafts, (i.e. the shaft which passes through the sterntube, but does not carry the propeller), made from carbon manganese steel are to be protected by a continuous bronze liner, where exposed to sea-water. Alternatively, the liner may be omitted provided the shaft is arranged to run in an oil lubricated bush with an approved oil sealing gland at the after end. Lengths of shafting between sterntubes and brackets, which are readily visible when the ship is in dry dock, may be protected by coatings of an approved type.

4.4.2 Means for the protection of screwshafts and tubeshafts are not required when the shafts are made of corrosion resistant material.

4.4.3 The diameter, d_p, of the protected forged steel screwshaft immediately forward of the forward face of the propeller boss or, if applicable, the forward face of the screwshaft flange, is to be not less than:

$$d_p = 100k\sqrt[3]{\frac{P}{R}\left(\frac{560}{\sigma_u + 160}\right)}\ \text{mm}$$

where

k = 1,22 for a shaft carrying a keyless propeller fitted on a taper, or where the propeller is attached to an integral flange, and where the shaft is fitted with a continuous liner, a coating of an approved type, or is oil lubricated and provided with an approved type of oil sealing gland

= 1,26 for a shaft carrying a keyed propeller and where the shaft is fitted with a continuous liner, a coating of an approved type, or is oil lubricated and provided with an approved type of oil sealing gland

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2 but is not to be taken as greater than 600 N/mm^2.

4.4.4 The diameter, d_p, of the screwshaft determined in accordance with *Vol 2, Pt 3, Ch 2, 4.4 Screwshafts and tube shafts 4.4.3* is to extend over a length not less than that to the forward edge of the bearing immediately forward of the propeller or 2,5d_p, whichever is the greater.

4.4.5 The diameter of the portion of the screwshaft and tube shaft forward of the length required by *Vol 2, Pt 3, Ch 2, 4.4 Screwshafts and tube shafts 4.4.4* to the forward end of the forward stern tube seal is to be determined in accordance with *Vol 2, Pt 3, Ch 2, 4.4 Screwshafts and tube shafts 4.4.3* with a *k* value of 1,15. The change of diameter from that determined with *k* = 1,22 or 1,26 to that determined with *k* = 1,15 should be gradual, *see Vol 2, Pt 3, Ch 2, 4.8 Flange connections of couplings*.

4.4.6 Screwshafts which run in sterntubes and tube shafts may have the diameter forward of the forward stern tube seal gradually reduced to the diameter of the intermediate shaft. Abrupt changes in shaft section at the screwshaft/tube shaft to intermediate shaft couplings are to be avoided, *see Vol 2, Pt 3, Ch 2, 4.8 Flange connections of couplings*.

4.4.7 The diameter of unprotected screwshafts and tube shafts of materials having properties as shown in *Table 2.4.1 Provisional 'A' value for use in unprotected screwshaft formula* is to be not less than:

$$d_{up} = 128A\sqrt[3]{\frac{P}{R}}$$

where

A is taken from *Table 2.4.1 Provisional 'A' value for use in unprotected screwshaft formula* .

Table 2.4.1 Provisional '*A*' value for use in unprotected screwshaft formula

Material	'*A*' Value
Stainless steel type 316 (austenitic)	0,71

Stainless steel type 431 (martensitic)	0,69
Manganese bronze	0,8
Nickel/aluminium bronze	0,65
Nickel copper alloy – monel 400	0,65
Nickel copper alloy – monel K 500	0,55
Duplex steels	0,49

4.4.8 The diameter of unprotected screwshafts of materials having properties as shown in *Table 2.4.1 Provisional 'A' value for use in unprotected screwshaft formula* forward of the forward stern tube seal is to be determined in accordance with *Vol 2, Pt 3, Ch 2, 4.4 Screwshafts and tube shafts 4.4.3* or *Vol 2, Pt 3, Ch 2, 4.4 Screwshafts and tube shafts 4.4.7*, whichever is less.

4.5 Hollow shafts

4.5.1 Where the thrust, intermediate, tube shafts and screwshafts have central holes with a diameter greater than 0,4 times the outside diameter, the equivalent diameter, d_e, of a solid shaft is not to be less than the Rule size, d, (of a solid shaft), where d_e is given by:

$$d_e = d_o \sqrt[3]{1 - \left(\frac{d_i}{d_o}\right)^4}$$

where

d_o = proposed outside diameter, in mm

d_i = diameter of central hole, in mm.

4.5.2 Where the diameter of the central hole does not exceed 0,4 times the outside diameter, the diameter is to be calculated in accordance with the appropriate requirements for a solid shaft.

4.6 Cardan shafts

4.6.1 Cardan shafts, used in installations having more than one propulsion shaftline, are to be of an approved design, suitable for the designed operating conditions including short term high power operation. Consideration will be given to accepting the use of approved cardan shafts in single propulsion unit applications if a complete spare interchangeable end joint is to be provided on board.

4.6.2 Cardan shaft ends are to be contained within substantial tubular guards that also permit ready access for inspection and maintenance.

4.7 Coupling bolts

4.7.1 Close tolerance fitted bolts transmitting shear are to have a diameter, d_b, at the flange joining faces of the couplings not less than:

$$d_b = \sqrt{\frac{240}{nD} \frac{10^6}{\sigma_u} \frac{P}{R}} \text{ mm}$$

where

n = number of bolts in the coupling

D = pitch circle diameter of bolts, in mm

σ_u = specified minimum tensile strength of bolts, in N/mm^2.

4.7.2 At the joining faces of couplings, other than within the crankshaft and at the thrust shaft/crankshaft coupling, the Rule diameter of the coupling bolts may be reduced by 5,2 per cent for craft classed exclusively for smooth water service.

4.7.3 Where dowels or expansion bolts are fitted to transmit torque in shear they are to comply with the requirements of *Vol 2, Pt 3, Ch 2, 4.7 Coupling bolts 4.7.1*. The expansion bolts are to be installed, and the bolt holes in the flanges are to be correctly aligned, in accordance with manufacturer's instructions.

4.7.4 The minimum diameter of tap bolts or of bolts in clearance holes at the joining faces of coupling flanges, pre-tensioned to 70 per cent of the bolt material yield strength value, is not to be less than:

$$d_R = 1{,}348\sqrt{\left(\frac{120\ 10^6 F\,P(1+C)}{R\,D} + Q\right)\frac{1}{n\ \sigma_y}}$$

where

d_R is taken as the lesser of:

(a) Mean of effective (pitch) and minor diameters of the threads.

(b) Bolt shank diameter away from threads. (Not for waisted bolts which will be specially considered.)

F = 2,5 where the flange connection is not accessible from within the ship

= 2,0 where the flange connection is accessible from within the ship

C = ratio of vibratory/mean torque values at the rotational speed being considered

D = pitch circle diameter of bolt holes, in mm

Q = external load on bolt in N (+ve tensile load tending to separate flange, –ve)

n = number of tap or clearance bolts

σ_y = bolt material yield stress in N/mm^2.

4.7.5 Consideration will be given to those arrangements where the bolts are pre-tensioned to loads other than 70 per cent of the material yield strength.

4.7.6 Where clamp bolts are fitted they are to comply with the requirements of *Vol 2, Pt 3, Ch 2, 4.7 Coupling bolts 4.7.4* and are to be installed, and the bolt holes in the flanges correctly aligned, in accordance with manufacturer's instructions.

4.8 Flange connections of couplings

4.8.1 The minimum thicknesses of the coupling flanges are to be equal to the diameters of the coupling bolts at the face of the couplings as required by *Vol 2, Pt 3, Ch 2, 4.7 Coupling bolts 4.7.1*, and for this purpose the minimum tensile strength of the bolts is to be taken as equivalent to that of the shafts. For intermediate, thrust shafts, and the inboard end of the screwshaft, the thickness of the coupling flange is in no case to be less than 0,20 of the diameter of the intermediate shaft as required by *Vol 2, Pt 3, Ch 2, 4.2 Intermediate shafts 4.2.1*

4.8.2 The fillet radius at the base of the coupling flange, integral with the shaft, is to be not less than 0,08 of the diameter of the shaft at the coupling. The fillets are to have a smooth finish and are not to be recessed in way of nut and bolt heads.

4.8.3 Where the propeller is attached by means of a flange, the thickness of the flange is to be not less than 0,25 of the actual diameter of the adjacent part of the screwshaft. The fillet radius at the base of the coupling flange is to be not less than 0,125 of the diameter of the shaft at the coupling.

4.8.4 Where couplings are separate from the shafts, provision is to be made to resist the astern pull.

4.8.5 Where a coupling is shrunk on to the parallel portion of a shaft or is mounted on a slight taper, e.g. by means of the oil pressure injection method, the assembly is to meet the requirements of *Vol 2, Pt 3, Ch 2, 4.11 Interference fit assemblies*

4.8.6 Transitions of diameters are to be designed with either a smooth taper or a blending radius. In general, a blending radius equal to the change in diameter is recommended.

4.9 Tooth couplings

4.9.1 The contact stress, S_c, at the flanks of mating teeth of a gear coupling is not to exceed that given in *Table 2.4.2 Allowable S_c values* , where

$$S_c = \frac{24,10^6 P}{R d_p b h z} \text{ N/mm}^2$$

d_p = pitch circle diameter of coupling teeth, in mm

b = tooth face width, in mm

h = tooth height, in mm

z = number of teeth (per coupling half).

Table 2.4.2 Allowable S_c values

Tooth material surfacetreatment	Allowable S_c value N/mm^2
Surface hardened teeth	19
Through hardened teeth	11

4.9.2 Where experience has shown that under similar operating and alignment conditions, a higher tooth loading can be accommodated, full details are to be submitted for consideration.

4.10 Flexible couplings

4.10.1 Details of flexible couplings are to be submitted, together with the manufacturer's rating capacity, for the designed operating conditions including short-term high power operation. Verification of coupling characteristics will be required.

4.10.2 In determining the allowable mean, maximum and vibratory torque ratings, consideration of the mechanical properties of the selected elastic element type in compression, shear and fatigue loading together with heat absorption/ generation is to be given.

4.10.3 In determining the allowable torque ratings of the steel spring couplings, consideration of the material mechanical properties to withstand fatigue loading, and overheating is to be given.

4.11 Interference fit assemblies

4.11.1 The interference fit assembly is to have a capacity to transmit a torque of $S.T_{max}$ without slippage.

NOTE

For guidance purposes only, $T_{max} = T_{mean}(1 + C)$where

C = is to be taken from *Table 2.4.3 'C' values for guidance purposes*

S = 2,0 for assemblies accessible from within the vessel

= 2,5 for assemblies not accessible from within the vessel.

Table 2.4.3 '*C*' values for guidance purposes

Coupling location	*C*
High speed shafting– I.C engine driven	0,3
High speed shafting– Electric motor or turbine driven	0,1
Low speed shafting– main or PTO stage gearing	0,1

4.11.2 The effect of any axial load acting on the assembly is to be considered.

4.11.3 The resulting equivalent von Mises stress in the assembly is not to be greater than the yield strength of the component material.

4.11.4 Reference marks are to be provided on the adjacent surfaces of parts secured by shrinkage alone.

4.12 Keys and keyways for propeller connections

4.12.1 Round ended or sled-runner ended keys are to be used, and the keyways in the propeller boss and cone of the screwshaft are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the screwshaft at the top of the cone. The sharp edges at the top of the keyways are to be removed.

4.12.2 Two screwed pins are to be provided for securing the key in the keyway, and the forward pin is to be placed at least one third of the length of the key from the end. The depth of the tapped holes for the screwed pins is not to exceed the pin diameter, and the edges of the holes are to be slightly bevelled. The omission of pins for keys for small diameter shafts will be specially considered.

4.12.3 The distance between the top of the cone and the forward end of the keyway is to be not less than 0,2 of the diameter of the screwshaft at the top of the cone.

4.12.4 The effective sectional area of the key in shear, is to be not less than:

$$\frac{155d^3}{\sigma_{\mathrm{u}} d_1}\ \mathrm{mm}^2$$

where

d = diameter, in mm, required for the intermediate shaft determined in accordance with *Vol 2, Pt 3, Ch 2, 4.2 Intermediate shafts*, based on material having a specified minimum tensile strength of 400 N/mm^2 and k = 1

d_1 = diameter of shaft at mid-length of the key, in mm

σ_u = specified minimum tensile strength (UTS) of the key material, N/mm^2.

4.12.5 The effective area in crushing of key, shaft or boss is to be not less than:

$$\frac{24d^3}{\sigma_{\mathrm{y}} d_1}\ \mathrm{mm}^2$$

where

σ_y = yield strength of key, shaft or boss material as appropriate, N/mm^2.

4.13 Keys and keyways for inboard shaft connections

4.13.1 Round ended keys are to be used and the keyways are to be provided with a smooth fillet at the bottom of the keyways. The radius of the fillet is to be at least 0,0125 of the diameter of the shaft at the coupling. The sharp edges at the top of the keyways are to be removed.

4.13.2 The effective area of the key in shear, A, is to be not less than:

$$A = \frac{126d^3}{\sigma_{\mathrm{u}} d_1}\ \mathrm{mm}^2$$

where

d = diameter, in mm, required for the intermediate shaft determined in accordance with *Vol 2, Pt 3, Ch 2, 4.2 Intermediate shafts*, based on material having a specified minimum tensile strength of 400 N/mm^2 and k = 1

d_1 = diameter of shaft at mid-length of the key, in mm

σ_u = specified minimum tensile strength (UTS) of the key material, N/mm^2.

Alternatively, consideration will be given to keys conforming to the design requirements of a recognised National Standard.

4.14 Corrosion resistant liners on shafts

4.14.1 Liners may be bronze, gunmetal, stainless steel or other approved alloy.

4.14.2 The thickness, t, of liners fitted on screwshafts or on tube shafts, in way of the bushes, is to be not less, when new, than given by the following formula: $t = \dfrac{D + 230}{32}$ mm

where

t = thickness of the liner, in mm

D = diameter of the screwshaft or tube shaft under the liner, in mm.

4.14.3 The thickness of a continuous liner between the bushes is to be not less than 0,75t.

4.14.4 Continuous liners are to be fabricated or cast in one piece.

4.14.5 Where liners consist of two or more lengths, these are to be butt welded together. In general, the lead content of the gunmetal of each length forming a butt welded liner is not to exceed 0,5 per cent. The composition of the electrodes or filler rods is to be substantially lead-free.

4.14.6 The circumferential butt welds are to be of multi-run, full penetration type. Provision is to be made for contraction of the weld by arranging for a suitable length of the liner containing the weld, if possible about three times the shaft diameter, to be free of the shaft. To prevent damage to the surface of the shaft during welding, a strip of heat resisting material covered by a copper strip should be inserted between the shaft and the liner in way of the joint. Other methods for welding this joint may be accepted if approved. The welding is to be carried out by an approved method and to the Surveyor's satisfaction.

4.14.7 Each continuous liner or length of liner is to be tested by hydraulic pressure to 2,0 bar after rough machining.

4.14.8 Liners are to be carefully shrunk onto the shafts by hydraulic pressure. Pins are not to be used to secure the liners.

4.14.9 Effective means are to be provided for preventing water from reaching the shaft at the part between the after end of the liner and the propeller boss.

4.15 Intermediate bearings

4.15.1 Long unsupported lengths of shafting are to be avoided by the fitting of steady bearings at suitable positions, *see Vol 2, Pt 5 Shaft Vibration and Alignment*

4.16 Sternbushes and sterntube arrangements

4.16.1 Where the sterntube or sternbushes are to be installed using a resin, of an approved type, the following requirements are to be met:

(a) Pouring and venting holes are to be provided at opposite ends with the vent hole at the highest point.
(b) The minimum radial gap occupied by the resin is to be not less than 6 mm at any one point with a nominal resin thickness of 12 mm.
(c) In the case of oil lubricated sterntube bearings, the arrangement of the oil grooves is to be such as to promote a positive circulation of oil in the bearing.
(d) Provision is to be made for the remote measurement of the temperature at the aft end of the aft bearing, with indication and alarms at the control stations.

4.16.2 The length of the bearing in the sternbush next to and supporting the propeller is to be as follows:

(a) For water lubricated bearings which are lined with rubber composition or staves of approved plastics material, the length is to be not less than four times the diameter required for the screwshaft under the liner.
(b) For water lubricated bearings lined with two or more circumferentially spaced sectors, of an approved plastics material, without axial grooves in the lower half, the length of the bearing is to be such that the nominal bearing pressure will not exceed 0,55 N/mm^2. The length of the bearing is to be not less than twice its diameter.
(c) For oil lubricated bearings of synthetic material the flow of lubricant is to be such that overheating, under normal operating conditions, cannot occur. The acceptable nominal bearing pressure will be considered upon application and is to be supported by the results of an agreed test programme.
(d) For bearings which are white-metal lined, oil lubricated and provided with an approved type of oil sealing gland, the length of the bearing is to be approximately twice the diameter required for the screwshaft and is to be such that the nominal bearing pressure will not exceed 0,8 N/mm^2. The length of the bearing is to be not less than 1,5 times its diameter.
(e) For bearings of cast iron and bronze which are oil lubricated and fitted with an approved oil sealing gland, the length of the bearing is, in general, to be not less than four times the diameter required for the screwshaft.

(f) Oil lubricated non-metallic bearings are to be manufactured from an approved material. The length of the bearing is to be such that the maximum approved bearing pressure is not exceeded for any limiting length to diameter ratio.

4.16.3 Sternbushes are to be adequately secured in housings.

4.16.4 Forced water lubrication is to be provided for all bearings lined with rubber or plastics. The supply of water may come from a circulating pump or other pressure source. Flow indicators are to be provided for the water service to plastics and rubber bearings. The water grooves in the bearings are to be of ample section and of a shape which will be little affected by weardown, particularly for bearings of the plastics type.

4.16.5 Oil lubricated bearings of synthetic material are to be supplied finished machined to design dimensions within a rigid tube. Means are to be provided to prevent rotation of the lining within the tube during operation.

4.16.6 The shut-off valve or cock controlling the supply of water is to be fitted direct to the after peak bulkhead, or to the sterntube where the water supply enters the sterntube forward of the bulkhead.

4.16.7 Oil sealing glands must be capable of accommodating the effects of differential expansion between hull and line of shafting for all sea temperatures in the proposed area of operation. This requirement applies particularly to those glands which span the gap and maintain oiltightness between the sterntube and the propeller boss.

4.16.8 Where a tank supplying lubricating oil to the sternbush is fitted, it is to be located above the load waterline and is to be provided with a low level alarm device in the machinery space, *see also Vol 2, Pt 3, Ch 2, 5.1 Unattended machinery 5.1.1*.

4.16.9 Where sternbush bearings are oil lubricated, provision is to be made for cooling the oil by maintaining water in the after peak tank above the level of the sterntube or by other approved means.

4.16.10 Means for ascertaining the temperature of the sternbush bearings are to be provided, e.g. monitoring of the temperature of the oil in the sterntube.

4.16.11 Where in-water surveys are required, means are to be provided for ascertaining the clearance in the sternbush with the vessel afloat.

4.17 Vibration and alignment

4.17.1 For the requirements for torsional, axial and lateral vibration, and for alignment of the shafting, *see Vol 2, Pt 5 Shaft Vibration and Alignment*

4.18 Rope guards

4.18.1 Rope guards that provide effective mechanical protection for all bearing sealing arrangements are to be provided.

4.19 Shaft brake and locking arrangements

4.19.1 Where two or more propulsion shafts are installed, each propulsion system is to be provided with shaft brakes and locking arrangements complying with *Vol 2, Pt 3, Ch 2, 4.19 Shaft brake and locking arrangements 4.19.2* and *Vol 2, Pt 3, Ch 2, 4.19 Shaft brake and locking arrangements 4.19.3*.

4.19.2 Shaft brakes for safely and speedily slowing down propulsion shafting systems are to be provided. Each shaft brake is to be capable of restraining the shaft system whilst the ship is being manoeuvred at slow speed and to hold the shaft while the shaft locking gear is being engaged. Shaft brakes are to be capable of functioning in a compartment that is flooded.

4.19.3 Means of safely securing the shafting systems in position are to be provided to permit the shaft to be locked in order to effect repairs whilst the ship is at sea and operating at a speed to maintain steering capability or not less than 7 knots, whichever is the greater.

Section 5
Control and monitoring

5.1 Unattended machinery

5.1.1 Where sterntube lubrication oil systems are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms indicated in *Table 2.5.1 Alarms*.

Table 2.5.1 Alarms

Item	Alarm
Sterntube lubricating oil tank level	Low
Sterntube bearing temperature (oil lubricated)	High

5.1.2 Where shaft systems incorporate a separate thrust block(s) and lubrication oil systems are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms indicated in *Table 2.5.2 Alarms - Thrust block lubrication*

Table 2.5.2 Alarms - Thrust block lubrication

Item	Alarm
Lubrication oil flow	Low
Lubrication oil temperature	High
Bearing temperature	High

5.2 Screwshaft Condition Monitoring (SCM)

5.2.1 For vessels where the notation SCM (Screwshaft Condition Monitoring) is requested, the requirements in either *Vol 2, Pt 3, Ch 2, 5.2 Screwshaft Condition Monitoring (SCM) 5.2.2* or *Vol 2, Pt 3, Ch 2, 5.2 Screwshaft Condition Monitoring (SCM) 5.2.3* are to be satisfied.

5.2.2 Oil lubricated bearings:

(a) Arrangements are to be provided to allow analysis of the lubricating oil. Oil samples are to be taken under service conditions and are to be representative of the oil within the sterntube, sampling arrangements are to meet the requirements of *Vol 2, Pt 7, Ch 3, 8.13 Lubricating oil contamination 8.13.6*.

(b) Bearing temperature sensor arrangement is to be designed with either:

  (i) sufficient redundancy in the event of failure of one sensing element and/or its associated cabling; or

  (ii) means to allow replacement of a damaged sensor without requiring dry-docking or divers.

(c) Facilities are to be provided for measurement of bearing weardown.

(d) Approved oil glands that are capable of being replaced without removal of the propeller or withdrawal of the screwshaft are to be fitted.

5.2.3 Water lubricated bearings:

(a) An approved means of monitoring and recording variations in the flow rate of lubricating water using two independent sensors is to be provided.

(b) An approved means of monitoring and recording variations in the shaft power transmission is to be provided.

(c) The maximum permitted weardown of the sternbush is to be indicated by the manufacturer. The maximum weardown allowance is to include both the absolute maximum permitted weardown and the weardown at which it is recommended to carry out an inspection and maintenance. An approved means of monitoring bearing weardown is to be provided. An alignment analysis considering both the newly installed clearance and the proposed absolute maximum allowable weardown, demonstrating that the system will operate satisfactorily within these two limits, is to be submitted and approved.

(d) For open loop systems the manufacturer is to submit information regarding the required standard of lubricating water filtration and lubricating water filters or separators are to be fitted which are able to achieve this requirement. The lubricating water supply is to be fitted with either continuous water sediment measuring equipment, turbidity monitoring equipment or an LR approved extractive sampling and testing procedure.

(e) Where a closed cycle water system is used, arrangements are to allow analysis of the water for at least the following parameters:

(i) Chloride content

(ii) Bearing material and metal particles content.

Water samples are to be representative of the water circulating within the sterntube.

(f) The shaft is to either be constructed of corrosion-resistant material or protected with a corrosion-resistant protective liner or coating approved by LR. Where a protective liner or coating is used, this is to meet the requirements of *Vol 2, Pt 3, Ch 2, 4.14 Corrosion resistant liners on shafts* and a means of assessing the condition of this liner is to be submitted and approved.

(g) Glands are to be capable of being replaced without withdrawal of the screwshaft.

(h) There is to be a shaft starting/clutch engagement block to inhibit starting the shaft until lubricating water flow has been established. This is to only act as a starting block; for lubricating water flow alarm, *see Table 2.5.3 Alarm and safeguard for water lubricated bearings*.

(i) Alternative arrangements are subject to special consideration.

Table 2.5.3 Alarm and safeguard for water lubricated bearings

Item	Alarm	Note
Lubricating water flow	Low	*See* 5.2.3(h)

■ *Section 1* Scope

1.1 Application

1.1.1 This Chapter defines the requirements for the design and service life of marine propellers for naval ships and is to be read in conjunction with the General Requirements for Machinery and Engineering Systems in *Vol 2, Pt 1, Ch 1 General Requirements for Classification of Engineering Systems* and *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*

1.1.2 The scope of this Chapter includes propellers for main propulsion, the support arrangements and the controls and systems necessary to maintain operation and functionality of the propeller. The contents are in respect of mechanical integrity of the propeller, control and monitoring systems and other support critical systems.

1.1.3 Marine propellers utilised for propulsion purposes are within the Mobility category as defined in *Vol 2, Pt 1, Ch 1, 3 Engineering system designation*

1.1.4 With the exception of the requirements of *Vol 2, Pt 4, Ch 1, 8 Propeller tolerances*, this Chapter is applicable to fully immersed propellers that are non-ducted. The propellers may be non-cavitating, partially cavitating or supercavitating.

1.1.5 Propeller designs for applications other than those specified in *Vol 2, Pt 4, Ch 1, 1.1 Application 1.1.4* will be specially considered.

1.1.6 *See Vol 2, Pt 1, Ch 3, 12 Propellers* for construction, installation and testing requirements.

1.2 Power ratings

1.2.1 In this Chapter where the dimensions of any particular components are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in *Vol 2, Pt 1, Ch 3, 4.3 Power ratings*

1.3 Propeller skew angle definition

1.3.1 The maximum skew angle of a propeller blade is defined as the angle, in projected view of the blade, between a line drawn through the blade geometric tip and the shaft centreline and a second line through the shaft centreline which acts as a tangent to the locus of the mid-points of the helical blade sections, *see Figure 1.1.1 Definition of skew angle*.

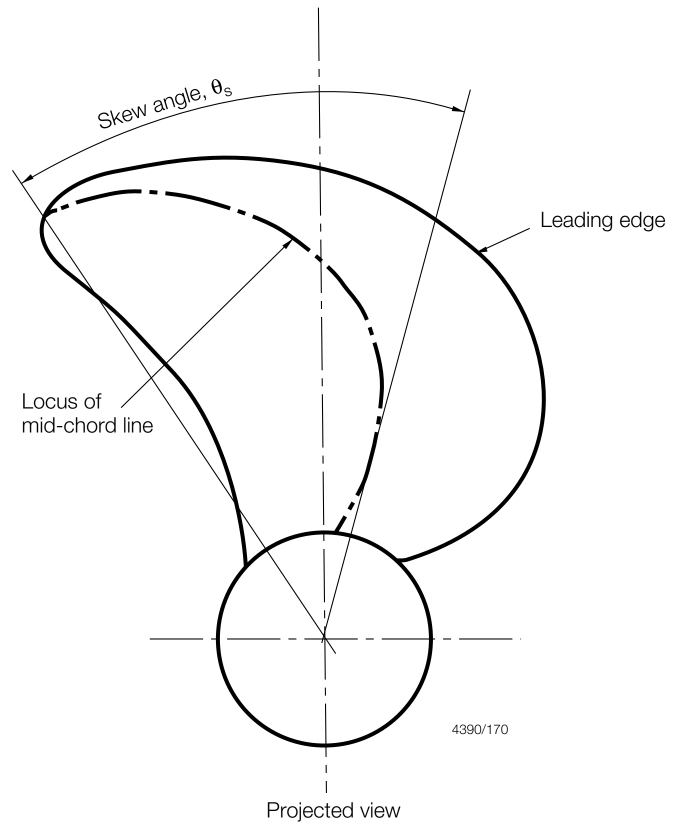


Figure 1.1.1 Definition of skew angle

■ *Section 2*
Principles

2.1 Design and operating principles

2.1.1 Marine propellers are to be designed in accordance with user defined operating and performance criteria, taking account of ship type and service operating envelope. In multiscrew ships, consideration is to be given to operating modes where one or more propeller is out of service.

2.1.2 Marine propellers are to be capable of continuous operation between the maximum and minimum output power at specified operating conditions, *see Vol 2, Pt 1, Ch 3, 4 Operating conditions* and within the operational service profile required by *Vol 2, Pt 4, Ch 1, 5.2 Plans 5.2.2* in this Chapter.

2.1.3 Marine propellers are to be designed and installed such that degradation or failure of any other propulsion system will not render the propeller inoperable.

2.1.4 Marine propellers are to be designed and installed such that power transmission can be maintained in the event of a single failure in an operational sub-system.

2.1.5 The propeller is to be capable of operating within defined vibration, cyclic or other loads during its service life.

2.1.6 Controllable pitch propellers shall be designed so that all blades are interchangeable and will fit into any blade seat on the hub.

2.2 Lifecycle principles

2.2.1 Propellers are to be operated and maintained such that the required performance, integrity and reliability can be achieved throughout the life of the ship.

2.2.2 To demonstrate continued compliance with the classification provisions for engineering systems (*see Vol 2, Pt 1, Ch 1, 2.1 Provisions 2.1.1*), surveys are to be carried out in accordance with the Regulations.

2.3 Enhanced assessment of manufacturing tolerance principles

2.3.1 Where the design of a propeller has used enhanced assessment methods for manufacturing tolerances as described in *Vol 2, Pt 4, Ch 1, 8.4 Enhanced assessment of manufacturing tolerances – Fast ships and craft* and *Vol 2, Pt 4, Ch 1, 8.5 Enhanced assessment of propeller manufacturing tolerances – Noise reduced propellers*, the ship will be eligible for the optional machinery class notation **AP1** or **AP2** as applicable. These optional class notations may be applied where the Owner requires detailed knowledge of a propeller's manufacturing tolerances and where noise or the effects of cavitation are required to be minimised for anticipated service conditions.

■ *Section 3* Acceptance criteria

3.1 General

3.1.1 Conformance with the performance criteria, together with any specific requirements of the applicable Rules, standards and legislation is to be demonstrated by the propeller manufacturer, shipbuilder and Navy/Operator to the satisfaction of Lloyd's Register (LR).

3.1.2 For propellers, the applicable Rules and Standards for classification are:

(a) LR *Rules for the Classification of Naval Ships*.
(b) ISO 484/1 Shipbuilding – Ship Screw Propellers – Manufacturing Tolerances, Part 1: *Propellers of Diameter greater than 2,5 m.*
(c) ISO 484/2 Shipbuilding – Ship Screw Propellers – Manufacturing Tolerances, Part 2: *Propellers of Diameter between 0,8 and 2,5 m inclusive.*
(d) Requirements of the Naval Administration as specified.
(e) Other specific Owner requirements. These are to be identified before commencement of design review or construction.
(f) LR Quality Scheme for Machinery.

Where it is proposed to use manufacturing tolerances other than those stated in the ISO Standards, these are to be agreed between the manufacturer and the Owner and advised to LR.

■ *Section 4* Routes to conformance

4.1 General

4.1.1 Documents relevant to the design, construction, installation, testing and operation of propellers are:

(a) LR's Rules for Propellers; *see Vol 2, Pt 4, Ch 1, 5 Documentation required for design review* to 10 of this Chapter and *Vol 2, Pt 1, Ch 3, 12 Propellers*
(b) The propeller manufacturer's recommendations.

4.1.2 The overall performance of installed propellers is to be demonstrated for conformance with the performance criteria specified. If necessary, these tests may be carried out in conjunction with the ship's operational pattern.

■ *Section 5* Documentation required for design review

5.1 Documentation

5.1.1 Particulars of the propellers are to be submitted with the plans, in triplicate, as described in *Vol 2, Pt 4, Ch 1, 5.2 Plans* to *Vol 2, Pt 4, Ch 1, 5.3 Calculations and information*.

5.2 Plans

5.2.1 Plans of the propeller, together with the following particulars are to be submitted:

(a) Maximum blade thickness of the expanded cylindrical section considered, in mm, excluding any allowance for fillet, T, in mm.
(b) Maximum shaft power (*see Vol 2, Pt 1, Ch 2 Requirements for Machinery and Engineering Systems of Unconventional Design*), P, in kW.
(c) Estimated ship speed at design loaded draught in the free running condition at maximum shaft power and corresponding revolutions per minute (*see Vol 2, Pt 4, Ch 1, 5.2 Plans 5.2.1* and *Vol 2, Pt 4, Ch 1, 5.2 Plans 5.2.1*).
(d) Revolutions per minute of the propeller at maximum power, R.
(e) Propeller diameter, D, in metres.
(f) Blade section nose-tail pitch at 25 per cent radius (for solid propellers only), $P_{0,25}$, in metres.
(g) Blade section nose-tail pitch at 35 per cent radius (for controllable pitch propellers only), $P_{0,35}$, in metres.
(h) Blade section nose-tail pitch at 60 per cent radius, $P_{0,6}$, in metres.
(i) Blade section nose-tail pitch at 70 per cent radius, $P_{0,7}$, in metres.
(j) Length of blade section of the expanded cylindrical section at 25 per cent radius (for solid propellers only), $L_{0,25}$, in mm.
(k) Length of blade section of the expanded cylindrical section at 35 per cent radius (for controllable pitch propellers only), $L_{0,35}$, in mm.
(l) Length of blade section of the expanded cylindrical section at 60 per cent radius, $L_{0,6}$, in mm.
(m) Rake at blade tip measured at shaft axis (backward rake positive, forward rake negative), A, in mm.
(n) Number of blades, N.
(o) Expanded area ratio, B.
(p) Material: type and specified minimum tensile strength.
(q) Skew angle, θ_s, in degrees, *see Figure 1.1.1 Definition of skew angle*.
(r) Connection of propeller to shaft, details of fit, push up, securing.
(s) Keyed connections details.
(t) Details of control/hydraulic system and pressures for controllable pitch propeller actuating mechanisms.
(u) Inertia of propeller assembly, specified either as GD^2 or Wk^2, in kgm^2.
(v) Total mass of propeller assembly, in kg.

5.2.2 The design operational service profile for the life of the ship is to be submitted. For fixed pitch propellers, this data is to be supplied in terms of a table or histogram showing the proportion of time anticipated to be spent within a particular speed range from zero to full speed. In the case of controllable pitch propellers, the combinator diagram is to be submitted and this is to show the propeller rotational speed, blade pitch angle at 0,7R and power absorbed against the control lever position. Additionally, for these types of propeller the proportion of time planned to be spent at a particular rotational speed, between the minimum and maximum speed ranges, is to be specified in terms of a histogram or table.

5.2.3 For propellers having a skew angle equal or greater than 50°, in addition to the particulars detailed in *Vol 2, Pt 4, Ch 1, 5.2 Plans 5.2.1* and *Vol 2, Pt 4, Ch 1, 5.2 Plans 5.2.2*, details are to be submitted of:

(a) Full blade section details at each radial station defined for manufacture.
(b) A detailed blade stress computation supported by the following hydrodynamic data for the estimated ahead mean ship effective wake condition and when absorbing full power:
    (i) Radial distribution of lift and drag coefficients, section inflow velocities and hydrodynamic pitch angles.
    (ii) Section pressure distributions calculated by either an advised inviscid or viscous procedure.

5.2.4 Where propellers, as defined in *Vol 2, Pt 4, Ch 1, 1.1 Application 1.1.4*, are intended for more than one operating regime, such as towing duties, a detailed blade stress calculation for each operating condition, indicating the rotational and ship speed, is to be submitted for consideration.

5.2.5 Where it is proposed to fit a fixed pitch propeller to the screwshaft without the use of a key, plans of the boss, tapered end of screwshaft, propeller nut and, where applicable, the sleeve, are to be submitted.

5.2.6 Where it is proposed to use a controllable pitch propeller, calculations are to be submitted which demonstrate the design integrity of the pitch control mechanism contained within the hub. Details of the associated piping arrangements are to be submitted. The submission is to include justification for the selection of the associated sealing arrangements within the hub, *see Vol 2, Pt 4, Ch 1, 7.5 Propeller boss and hubs 7.5.3*.

5.3 Calculations and information

5.3.1 In cases where the vessel has been the subject of model wake field tests, a copy of the results is to be submitted together with details of the model dimensions, scale and test conditions.

5.3.2 The following information is to be submitted as applicable:

(a) For controllable pitch propellers, plans (in diagrammatic form) of the hydraulic systems together with pipe material and working pressures.
(b) Details of control engineering aspects in accordance with *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*
(c) Calculations or relevant documentation indicating the suitability of all components for short-term high power operation. Where undertaken, fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads.
(d) For cases where the propeller material is not specified in *Table 1.6.1 Materials for propellers*, details of the chemical composition, mechanical properties and density are to be provided, together with results of fatigue tests in artificial sea water (3 per cent NaCl) to enable a value for *U* to be assigned.

5.3.3 Methods for demonstrating compliance with requirements for class notations **AP1** and **AP2** are to be submitted where applicable.

■ *Section 6* Materials

6.1 Castings for propellers

6.1.1 Castings for propellers and propeller blades are to comply with the requirements of *Rules for the Manufacture, Testing and Certification of Materials, July 2015*, *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). The chemical composition and mechanical properties of steel castings are given in *Ch 4, 5 Castings for propellers* and those of the copper alloys are given in *Ch 9, 1 Castings for propellers*

6.1.2 The specified minimum tensile strength of the castings is to be not less than stated in *Table 1.6.1 Materials for propellers*. The values of *U* in *Table 1.6.1 Materials for propellers* relate to castings of less than 25 tonnes in weight.

Table 1.6.1 Materials for propellers

Material	Specified minimum tensile strength N/mm^2	*G* Density g/cm^3	*U* Allowable stress N/mm^2
Carbon steels	400	7,9	20,6
Low alloy steels	440	7,9	20,6
13% chromium stainless steels	540	7,7	41
Chromium – nickel austenitic stainless steel	450	7,9	41
Duplex stainless steels	590	7,8	41

Grade Cu 1 Manganese bronze (high tensile brass)	440	8,3	35
Grade Cu 2 Ni-Manganese bronze (high tensile brass)	440	8,3	35
Grade Cu 3 Ni-Aluminium bronze	590	7,6	53
Grade Cu 4 Mn-Aluminium bronze	630	7,5	45

6.1.3 Spheroidal cast iron load transmitting components of controllable pitch mechanisms, are to be manufactured, tested and certified in accordance with *Ch 7 Iron Castings* of the Rules for Materials, and have an elongation of not less than 12 per cent.

■ *Section 7*
Propeller design

7.1 Minimum blade thickness

7.1.1 For propellers having a skew angle of 25° or less, as defined in *Vol 2, Pt 4, Ch 1, 1.3 Propeller skew angle definition 1.3.1*, the minimum blade thickness, *T*, of the propeller blades at 25 per cent radius for solid propellers, 35 per cent radius for controllable pitch propellers, neglecting any increase in each case due to fillets, and at 60 per cent radius, is to be not less than:

$$T = \frac{0,5KVZ}{\left(0,11ENLU_a - KWZ\right)} + 2450\sqrt{\frac{PCM}{RF\left(0,11ENLU_a - KWZ\right)}}\ \mathrm{mm}$$

where

L = $L_{0,25}$, $L_{0,35}$, or $L_{0,6}$ as appropriate

K = $\dfrac{GBR^2D^3}{673}$

G = density of the blade material in g/cm^3, *see Table 1.6.1 Materials for propellers*

U_a = design allowable stress in N/mm^2 derived from the allowable stress *U*, by the relationship

= $U_a = \varphi_u U$

where

φ_u is a factor in the range unity to 1,5 and is governed by the design operational profile of the ship. If 50 per cent or more of the design life of the propeller is to be spent operating at powers below 0,4*P*, the value of φu is governed by the anticipated design life number of revolutions (n) that the propeller will experience within the power range 0,75*P* to *P* of the propulsion machinery. As such, for bronze and stainless steel alloys:

If n ≤ 10^7 revolutions $\varphi_u = 1,5$

If $10^7 < n \le 10^9$ revolutions $\varphi_u = 3,25 - \dfrac{\log_{10}(n)}{4}$

If n > 10^9 revolutions $\varphi_u = 1,0$

For other operational profiles, the value of φ_u must be specially justified.

When high damping alloys are used, φ_u is to be taken as unity for all values of *n*.

U = allowable stress in N/mm^2, *see Vol 2, Pt 4, Ch 1, 7.1 Minimum blade thickness 7.1.4*, *Vol 2, Pt 4, Ch 1, 7.1 Minimum blade thickness 7.1.5* and *Table 1.6.1 Materials for propellers*

$$E = \frac{actualsectionmodulus}{0,11T^2L}$$

The coefficient Z is given by *Table 1.7.1 Values of Z* .

Table 1.7.1 Values of *Z*

Per cent radius	25	35	60
Fixed pitch propellers	0,5	—	0,36
Controllable pitch propellers	—	0,53	0,46

7.1.2 For solid propellers at 25 per cent radius:

C = 1,04

$$C = 1,04$$

$$F = \frac{P_{0,25}}{D} + 0,70$$

$$M = \lambda_T\left(1 + \frac{3,75D}{P_{0,7}}\right) + 2,03\,\lambda_Q\left(\frac{P_{0,25}}{D}\right)$$

For controllable pitch propellers at 35 per cent radius:

C = 1,72

$$F = \frac{P_{0,35}}{D} + 1,34$$

$$M = \lambda_T\left(1 + \frac{3,75D}{P_{0,7}}\right) + 1,45\,\lambda_Q\left(\frac{P_{0,35}}{D}\right)$$

For all propellers at 60 per cent radius:

C = 4,17

$$F = \frac{P_{0,6}}{D} + 3,75$$

$$M = \lambda_T\left(1 + \frac{3,75D}{P_{0,7}}\right) + 0,84\,\lambda_Q\left(\frac{P_{0,6}}{D}\right)$$

The value of W is to be taken as 0,16 for fixed pitch propellers and 0,12 for controllable pitch propellers.

The parameter V is the centrifugal bending moment lever acting at each of the Rule stress sections, in mm. For linear distributions of rake along the blade, the value of V can be determined from the following relationships:

$$V_{0,25} = \frac{A}{3,85F}$$

$$V_{0,35} = \frac{A}{3,23F}$$

$$V_{0,60} = \frac{A}{1,84F}$$

When non-linear distributions of blade rake are used, the value of V must be calculated individually for each stress section and the supporting calculation submitted along with the other information required in *Vol 2, Pt 4, Ch 1, 5.2 Plans 5.2.1*

For optimum free-running propellers, the values of λ_T and λ_Q can be taken from *Table 1.7.2 Values of λ_T and λ_Q*

Table 1.7.2 Values of λ_T and λ_Q

Per cent radius		25	35	60
Fixed pitch propellers	λ_T	0,45	—	0,14
	λ_Q	0,62	—	0,13
Controllable pitch propellers	λ_T	—	0,38	0,15
	λ_Q	—	0,48	0,14

7.1.3 For non-optimum and tip reduced circulation propellers, the values of the parameters λ_T and λ_Q are to be derived from the following expressions for 25, 35 and 60 per cent Rule radii, as applicable:

$$\lambda_T = \left[\frac{\int_x^{1,0} F'_T \bullet \xi \, d\xi}{\int_x^{1,0} F'_T d\xi} - x\right] \bullet \frac{\int_x^{1,0} F'_T d\xi}{\int_{x_h}^{1,0} F'_T d\xi}$$

and

$$\lambda_Q = \frac{\dfrac{\int_x^{1,0} F'_Q \bullet \xi \, d\xi}{\int_x^{1,0} F'_Q d\xi} - x}{\dfrac{\int_x^{1,0} F'_Q \bullet \xi \, d\xi}{\int_x^{1,0} F'_Q d\xi}} \bullet \frac{\int_x^{1,0} F'_Q d\xi}{\int_{x_h}^{1,0} F'_Q d\xi}$$

where

ξ = a non-dimensional radius between the integration limits

x = the Rule non-dimensional radius, 0,25, 0,35 or 0,6 whichever is appropriate

x_h = either the boss or hub non-dimensional radius depending on whether a solid or controllable pitch propeller is being considered

F'_T = elemental thrust forces acting on the blade sections

F'_Q = elemental torque forces acting on the blade sections.

7.1.4 The fillet radius between the root of a blade and the boss of a propeller is to be not less than the Rule thickness of the blade or equivalent at this location. Composite radiused fillets or elliptical fillets which provide a greater effective radius to the blade are acceptable and are to be preferred. Where fillet radii of the required size cannot be provided, the value of *U* is to be multiplied by

$$\left(\frac{r}{T}\right)^{0,2}$$

where

r = proposed fillet radius at the root, in mm

T = Rule thickness of the blade at the root, in mm.

Where a propeller has bolted-on blades, consideration is also to be given to the distribution of stress in the palms of the blades. In particular, the fillets of recessed bolt holes and the lands between bolt holes are not to induce stresses which exceed those permitted at the outer end of the fillet radius between the blade and the palm. Counterbored bolt holes in blade flanges are to be provided with adequate fillet radii at the bottom of the counter bore.

7.1.5 The value U, when used for determining U_a, may be increased by 10 per cent for twin screw and outboard propellers of triple screw ships and craft.

7.1.6 For propellers having skew angles of greater than 25°, but less than 50°, the mid-chord thickness. $T_{sk0,6}$, at the 60 per cent radius is to be not less than:

$T_{sk0,6} = 0,54T_{0,6}\sqrt{(1+0,1\,\theta_s)}$ mm

The mid chord thickness, $T_{sk\ root}$, at 25 or 35 per cent radius, neglecting any increase due to fillets, is to be not less than:

$$T_{sk\ root} = 0,75T_{root}\sqrt[4]{(1+0,1\theta_s)}\ \text{mm}$$

where

θ_s = proposed skew angle as defined in *Vol 2, Pt 4, Ch 1, 1.3 Propeller skew angle definition 1.3.1*

$T_{0,6}$ = thickness at 60 per cent radius, calculated by *Vol 2, Pt 4, Ch 1, 7.1 Minimum blade thickness 7.1.1*

T_{root} = thickness at 25 per cent radius or 35 per cent radius, calculated by *Vol 2, Pt 4, Ch 1, 7.1 Minimum blade thickness 7.1.1*

The thickness at the remaining radii are to be joined by a fair curve and the sections are to be of suitable aerofoil section.

7.1.7 Results of detailed calculations, where carried out, are to be submitted.

7.1.8 Where the design of a propeller has been based on analysis of reliable wake survey data in conjunction with a detailed fatigue analysis and is deemed to permit scantlings less than required by *Vol 2, Pt 4, Ch 1, 7.1 Minimum blade thickness 7.1.1* but maintaining the required value of U_a, a detailed stress analysis for the blades is to be submitted for consideration.

7.2 Fluid channels in propellers and blades

7.2.1 Where it is required to emit air or other fluids from the blades of propellers, then the channels conducting the fluid are to be arranged such that they pass through low stressed regions of the blades.

7.2.2 Full details of any fluid channels in the propeller and its blades, including the method of manufacture and the details of any closing plates together with any required welding processes and procedures, are to be submitted for consideration together with supporting stress calculations. Consideration is to be extended to the method of transferring the emission fluid though the propulsion system to the propeller and the safety devices provided to accommodate the effects of a failure of the fluid transfer system.

7.2.3 In cases where it is considered necessary to introduce holes, passing from the suction to pressure surfaces of the blades, in order to control cavitation in the blade root sections, the details of these arrangements, together with supporting calculations, are to be submitted for consideration. Such holes are to be designed with blending radii from the hole to the blade surface but need not be of constant profile. Furthermore, if any throttling or other arrangements are required to be fitted within the holes, full design calculations and fitting details are to be submitted.

7.3 Interference fit of keyless propellers

7.3.1 The symbols used in *Vol 2, Pt 4, Ch 1, 7.3 Interference fit of keyless propellers 7.3.2* are defined as follows:

d_1 = diameter of the screwshaft cone at the mid-length of the boss or sleeve, in mm

d_3 = outside diameter of the boss at its mid-length, in mm

d_i = bore diameter of screwshaft, in mm

$k_3 = \dfrac{d_3}{d_1}$

$I = \dfrac{d_i}{d_1}$

$p_1 = \dfrac{2M}{A_1\,\theta_1 V_1}\left(-1+\sqrt{1+V_1\left(\dfrac{F^2{}_1}{M^2}+1\right)}\right)$

A_1 = contact area fitting at screwshaft, in mm^2

B_3 = $\dfrac{1}{E_3}\left(\dfrac{k_3^2+1}{k_3^2-1}+v_3\right)+\dfrac{1}{E_1}\left(\dfrac{1+l^2}{1-l^2}-v_1\right)$

C = 0 for turbine installations or electric propulsion

= $\dfrac{\text{vibratory torque at themaximum servicespeed}}{\text{mean torque at themaximum service speed}}$

= for oil engine installations

E_1 = modulus of elasticity of screwshaft material, in N/mm^2

E_3 = modulus of elasticity of propeller material, in N/mm^2

F_1 = $\dfrac{2000Q}{d_1}(1+C)$

M = propeller thrust, in N

Q = mean torque corresponding to P and R as defined in *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*, in Nm

T_1 = temperature at time of fitting propeller on shaft, in °C

V_1 = $0,51\left(\dfrac{\mu_1}{\theta_1}\right)^2-1$

α_1 = coefficient of linear expansion of screwshaft material, in mm/mm/°C

α_3 = coefficient of linear expansion of propeller material, in mm/mm/°C

θ_1 = taper of the screwshaft cone, but is not to exceed $\frac{1}{15}$ on the diameter, i.e. $\theta_1 \le \frac{1}{15}$

μ_1 = coefficient of friction for fitting of boss assembly on shaft

= 0,13 for oil injection method of fitting

v_1 = Poisson's ratio for screwshaft material

v_3 = Poisson's ratio for propeller material.

7.3.2 Where it is proposed to fit a keyless propeller by the oil shrink method, the pull-up, δ on the screwshaft is to be not less than:

$$\sigma_o = \frac{d_1}{\theta_1}\left(p_1 B_3 + \left(\alpha_3 - \alpha_1\right)\left(35 - T_1\right)\right)\ \text{mm}$$

The yield stress or 0,2 per cent proof stress, σ_o of the propeller material is to be not less than:

$$\sigma_o = \frac{1,4}{B_3}\left(\frac{\theta_1 \delta_p}{d_1} + T_1\left(\alpha_3 - \alpha_1\right)\right)\frac{\sqrt{3k_3^4+1}}{k_3^2-1}\ \text{N/mm}^2$$

where

δ_p = proposed pull-up at the fitting temperature

The start point load, W, to determine the actual pull-up is to be not less than:

$$W = A_1\left(0,002 + \frac{\theta_1}{20}\right)\left(p_1 + \frac{18}{B_3}(\alpha_3 - \alpha_1)\right)\text{N}$$

7.4 Keyed propellers pushed up by a hydraulic nut

7.4.1 Calculations are to be undertaken to show that the proof stress of the boss material is not exceeded in way of the keyway root fillet radius. In order to reduce the likelihood of fretting, a grip stress of not less than 20 N/mm^2 between boss and shaft is to be achieved.

7.5 Propeller boss and hubs

7.5.1 The forward edge of the bore of the propeller boss is to be rounded to a 6 mm radius. In the case of keyed propellers, the length of the forward fitting surface is to be about one diameter.

7.5.2 Drilling holes through propeller bosses is to be avoided, except where it is essential to the design.

7.5.3 The mechanisms contained within the hubs of controllable pitch propellers and their associated piping arrangements are to be designed to be capable of operating within defined vibration, cyclic or other loads during their service life. As such, a factor of safety of 1,5 is to be demonstrated against all modes of failure for components in the pitch control system at full power operating conditions. Similarly, the sealing systems within the hub mechanism are to be selected to provide integrity of operation within defined survey or inspection intervals.

■ *Section 8* Propeller tolerances

8.1 General

8.1.1 This section applies to conventional fixed and controllable pitch propellers, ducted propellers, supercavitating and surface piercing propellers.

8.1.2 All propellers are to have manufacturing tolerances specified on the design drawings.

8.1.3 Adequate records defining the manufactured dimensions of the propeller are to be maintained in order that subsequent compliance with the requirements of this Section can be demonstrated.

8.1.4 The fitting of the propeller to the shaft interface is dealt with separately in *Vol 2, Pt 4, Ch 1, 7.3 Interference fit of keyless propellers* and *Vol 2, Pt 4, Ch 1, 7.4 Keyed propellers pushed up by a hydraulic nut* .

8.2 Minimum requirements

8.2.1 As a minimum requirement for all naval surface ship types, with the exception of work boats and very low performance craft having speeds below 10 knots, the Class 1 requirements of the ISO 484/1 or 484/2 specifications are to be applied.

8.2.2 For work boats and very low performance craft having speeds below 10 knots, the Class 2 requirements of the ISO 484/1 or 484/2 specifications may be applied.

8.3 Balancing

8.3.1 After the production processes and assembly, where appropriate, have been completed, the propeller must be statically balanced by an approved method, details of which are to be submitted.

8.3.2 For fixed pitch propellers, the propeller and cone must each be statically balanced according to the requirements of *Table 1.8.1 Balancing requirements*

Table 1.8.1 Balancing requirements

Propeller rotational speed	Balance criterion
Up to 200 rpm	± 0,225 kgf.m/tonne
200 to 400 rpm	$\pm \dfrac{9000}{R^2}$ kgf.m/tonne

8.3.3 For controllable pitch propellers the blades, hubs and fairing cones are to be balanced separately. For propellers having rotational speeds between 200 and 400 rpm, the maximum allowable total imbalance is $\pm 15000/R^2$ kgf.m/tonne. For propellers having rotational speeds less than 200 rpm, the maximum allowable total imbalance is ±0,375 kgf.m/tonne.

8.3.4 For propeller rotational speeds greater than 400 rpm, special consideration will be given to the balancing method, whether it should incorporate dynamic effect and the balance limits. Dynamic balancing tests may be required for high rotational speed propellers where significant out-of-balance couples can be exerted on the shafting. Such tests are to be agreed between the manufacturer and Owner and advised to LR.

8.4 Enhanced assessment of manufacturing tolerances – Fast ships and craft

8.4.1 For ships and craft having displacements below 500 tonnes and speeds in excess of 25 knots that require the enhanced assessment of propeller manufacturing tolerances notation **AP1**, the Class S requirements of the ISO 484/1 or 484/2 specifications are to be applied in addition to *Vol 2, Pt 4, Ch 1, 8.4 Enhanced assessment of manufacturing tolerances – Fast ships and craft 8.4.2* to *Vol 2, Pt 4, Ch 1, 8.4 Enhanced assessment of manufacturing tolerances – Fast ships and craft 8.4.5*.

8.4.2 In addition to the leading edge templates required by *Vol 2, Pt 4, Ch 1, 8.4 Enhanced assessment of manufacturing tolerances – Fast ships and craft 8.4.1*, radial root fillet templates are to be provided at 0 per cent, 5 per cent, 10 per cent and 20 per cent of the chordal length from the leading edge in the blade roots.

8.4.3 A mid-fillet, in the radial sense, blade leading edge chordal template is to be provided. This template is to define the root fillet geometry from the leading edge to the 20 per cent chordal location from the leading edge and is to be based on the designed back and face surfaces of the propeller blade. The manufactured blade profile is to be demonstrated to lie within a tolerance band of ± 0,5 mm.

8.4.4 The diameter of the propeller boss is to be checked at four equi-distant axial stations along the boss length. These stations are to include the forward and aft faces of the propeller boss. The diameters measured at the four axial stations of the boss must be shown to lie within ± 1 mm from the design value.

8.4.5 If the design incorporates through blade penetrations, two plug templates, one in the radial and the other in the chordal direction, must be provided for each type of penetration so as to define the design penetration to blade surface geometry. The manufactured intersection geometry must be shown to lie within ± 0,5 mm of the design intent. Additionally, the tolerance for the surface finish of the intersection geometry shall be 3 μm Ra.

8.5 Enhanced assessment of propeller manufacturing tolerances – Noise reduced propellers

8.5.1 For ships having noise reduced propellers and requiring the enhanced assessment of propeller manufacturing tolerances notation **AP2**, the Class S requirements of the ISO 484/1 or 484/2 specifications are to be applied in addition to *Vol 2, Pt 4, Ch 1, 8.5 Enhanced assessment of propeller manufacturing tolerances – Noise reduced propellers 8.5.2* to *Vol 2, Pt 4, Ch 1, 8.5 Enhanced assessment of propeller manufacturing tolerances – Noise reduced propellers 8.5.5*.

8.5.2 The requirements of *Table 1.8.2 Manufacturing tolerances* are to be satisfactorily achieved.

8.5.3 In order to adequately control the blade shape, the local pitch errors of any two consecutive measurements are not to differ by more than half the local pitch tolerance envelope.

8.5.4 To control the shape of the pressure face of the blade, the algebraic sum of the local pitch errors of any two consecutive measurements is not to exceed 75 per cent of the local pitch tolerance envelope.

8.5.5 To limit chordwise deviations of the suction surface of the blade, local thickness errors are not to differ by more than half the thickness tolerance envelope between any two consecutive measurements.

Table 1.8.2 Manufacturing tolerances

Dimension	Tolerance
Angular spacing between blade reference lines at all radii	± 0,25 degrees
Difference between blade reference line and section leading or trailing edge	± 0,5% of the chord length with a minimum value of ± 1 mm
Fit of template inside the hook of the leading edge	+ 0 mm – 0,2 mm
Fit of face templates and outside the hook of leading edge templates	+ 0 mm – 0,5 mm
Blade axial position	± 0,25% of propeller diameter with a minimum value of ± 5 mm
Boss diameters	± 0,5 mm
Boss length	± 0,5 mm
Surface finish	< 1,6μm

■ *Section 9* Piping systems

9.1 General

9.1.1 The piping system for a controllable pitch propeller is to comply with the general design requirements given in *Vol 2, Pt 7, Ch 3 Machinery Piping Systems*

9.1.2 The specific requirements for lubricating hydraulic oil systems and standby arrangements are given in *Vol 2, Pt 7, Ch 3 Machinery Piping Systems*

9.1.3 The hydraulic power operating systems are to be provided with arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system.

■ *Section 10* Control and monitoring

10.1 General

10.1.1 Control and monitoring are to comply with the requirements of *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*

10.2 Automatic and remote controls

10.2.1 Where controllable pitch propellers are fitted with automatic or remote controls so that under normal operating conditions they do not require any manual intervention by the operators, they are to be provided with the alarms and safety arrangements required by 10.2.2, 10.2.3 and *Table 1.10.1 Alarms*

Table 1.10.1 Alarms

Item	Alarm	Note
Hydraulic system pressure	Low	—
Hydraulic oil supply tank level	Low	—
Hydraulic oil temperature	High	Where an oil cooler is fitted
Power supply to the control system between the remote control station and hydraulic actuator	Failure	Failure of any power supply to a control system is to operate an audible and visual alarm
Propulsion motor	Overload	*See Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*

10.2.2 For controllable pitch propellers for main propulsion, a standby or alternative power source of actuating medium for controlling the pitch of the propeller blades is to be provided. Automatic start of the standby pump supplying hydraulic power for pitch control is to be provided.

10.2.3 Controllable pitch propellers are to be provided with an indication of shaft speed, an indication of direction, an indication representative of the magnitude of thrust and an indication of propeller pitch as a measure of the propeller blade or actuator movement at each station from which it is possible to control shaft speed or propeller pitch.

■ Section 1 Scope

1.1 General

1.1.1 For the purposes of these Rules, a water jet propulsion unit is described as a machine which takes in water, by means of a suitable inlet and conduit, and accelerates the mass of water using an impeller and nozzle to form a jet propulsion system. The water jet system comprises the unit and its associated actuation and control devices. The detail of the prime mover is excluded but not its effect on the water jet system.

1.1.2 This Chapter defines the requirements for the design and service life of marine water jet propulsion systems and is to be read in conjunction with the requirements for Machinery and Engineering Systems in *Vol 2, Pt 1, Ch 1 General Requirements for Classification of Engineering Systems* and *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*.

1.1.3 The requirements for a fixed or steerable water jet propulsion system rated at 500 kW and above, which is integral with the ship's hull structure and forms a means of main propulsion, are detailed in this Chapter. This includes support arrangements, controls and the systems necessary to maintain operation and functionality of the water jet unit.

1.1.4 These requirements relate to water jets driven by axial or mixed flow pumps. Where units driven by radial flow pumps or inducers are proposed, details are to be submitted for consideration.

■ Section 2 General requirements

2.1 Water jet arrangement

2.1.1 In general, for a ship to be assigned an unrestricted service notation, a minimum of two water jet systems is to be provided where these form the sole means of propulsion. For ships where a single water jet system is the sole means of propulsion or steering, a detailed engineering and safety justification is to be evaluated by LR, *see Vol 2, Pt 4, Ch 2, 2.3 Calculations and information 2.3.22*. This evaluation process will include a Risk Assessment (RA) in accordance with *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*, to verify that sufficient levels of redundancy and monitoring are incorporated in the water jet unit's support systems and operating equipment.

2.1.2 Water jet propulsion units are to be capable of continuous operation between their maximum and minimum output power rating at specified operating conditions, *see Vol 2, Pt 1, Ch 3, 4 Operating conditions*, and within the operational service profiles defined by *Vol 2, Pt 4, Ch 2, 2.3 Calculations and information 2.3.11* and *Vol 2, Pt 4, Ch 2, 2.3 Calculations and information 2.3.12*.

2.1.3 It is the Shipbuilder's responsibility to ensure that all of the installed equipment is suitable for operation in the location and under the environmental conditions defined in *Vol 2, Pt 1, Ch 3, 4 Operating conditions*. Where anticipated environmental conditions are outside these limits or where additional conditions are to be considered, such as vibration and impulsive accelerations, requirements and details of compliance are to be submitted to LR.

2.2 Documentation required for design review

2.2.1 Plans, in triplicate, and information as detailed below and in *Vol 2, Pt 4, Ch 2, 2.3 Calculations and information* and *Vol 2, Pt 4, Ch 2, 2.4 Risk Assessment (RA)*, are to be submitted for consideration.

2.2.2 General arrangement plans showing details of the following:

(a) Shafting assembly indicating bearing positions;
(b) Steering assembly;
(c) Reversing assembly;
(d) Shaft sealing arrangement assembly;
(e) Longitudinal section of the complete water jet unit.

2.2.3 Detailed and dimensioned plans indicating scantlings, materials of construction and, where applicable, surface finish of the following:

(a) Arrangement of the system, including the intended method of attachment to the hull and building-in, tunnel geometry, shell openings, method of stiffening, reinforcement, etc;
(b) All torque transmitting components, including the shafting system, impeller and stator if fitted;
(c) Steering components, together with a description and line diagram of the control circuit. This is to include steerable exit water jet nozzles, where fitted;
(d) Components of the retractable buckets where these are used for providing astern thrust;
(e) The bearing or bearings absorbing the thrust and supporting the impeller, together with the method of lubrication;
(f) Details of any shafting support or guide vanes used in the water jet system.

2.2.4 Schematic plans of the lubrication and hydraulics required for steering/reversing systems, together with pipe material, relief valves and the working pressures required.

2.3 Calculations and information

2.3.1 Strength calculations based on fatigue considerations incorporating the maximum continuous torque rating and the most 'onerous' operating condition, *see Vol 2, Pt 4, Ch 2, 2.3 Calculations and information 2.3.12*, including any short-term high power operation, and including the effects of mean and fluctuating loads, transitory loadings, residual stress allowances and stress raisers, for the following components:

(a) Impeller, stator and any bolting arrangements supporting propulsion or steering loads;
(b) Shaft supports and coupling arrangements;
(c) Inlet guide vanes, if fitted;
(d) Steering components, including the lugs of steerable nozzles, where fitted;
(e) Retractable buckets and associated mechanisms which are used to provide astern thrust. A calculation of the hydrodynamic transient loads is to be made for each design and is to include the full ahead to full astern condition. The calculation procedure used is to be supported, where possible, with full scale or model test data, or satisfactory service experience, to validate the design method.

2.3.2 Calculations supporting the connection method of the impeller to the shaft, including details of the fit, push-up, securing, bolting arrangements, etc. In addition, where lengths of shafts are joined using couplings of the shrunk element type, full particulars of the method of achieving the grip force.

2.3.3 Calculations relating to the design of the shaftline as evidence of compliance with *Vol 2, Pt 3, Ch 2 Shafting Systems*.

2.3.4 Torsional vibration calculations of the complete dynamic system, in accordance with the relevant requirements included in *Vol 2, Pt 5, Ch 1 Torsional Vibration*.

2.3.5 Shaft lateral vibration calculations, where required by *Vol 2, Pt 5, Ch 3 Lateral Vibration*.

2.3.6 Calculations of the tunnel strength and supporting structure.

2.3.7 A calculation to determine the stresses within the impeller blade.

2.3.8 A calculation of the blade natural frequency for the impeller blades.

2.3.9 A calculation of the relative blade passing frequency between the rotor and stator blades.

2.3.10 The value of the fluctuating stresses during one revolution of the impeller and from transient loadings.

2.3.11 Details of the power/speed range of operation, indicating the maximum continuous torque rating, together with the associated thrusts; this information may be presented in the form of a characteristic curve for the water jet.

2.3.12 The water jet thrust for the assessment of the strength condition being considered is to be as follows:

(a) For ships which are intended to operate predominantly in a free-running condition and at steady service conditions, the water jet thrust is to correspond to the absorption of the maximum continuous shaft power and corresponding revolutions per minute, giving the maximum torque for which the shaft system is approved.
(b) For ships which are designed for several operating conditions, the maximum thrust associated with these conditions and the absorption of the corresponding power, in addition to the maximum continuous powering condition, are to be used in the calculation.
(c) The justification for the thrust selected is to be submitted for consideration in the approval process and this is to include the ship type and the ship speed at the conditions considered.

2.3.13 A justification that the water jet system will meet the self-priming criteria, *see Vol 2, Pt 4, Ch 2, 3.1 General 3.1.6*.

2.3.14 Specifications of materials and NDE procedures for components essential for propulsion and steering operation and, in the case of the impeller and stator, the yield strength and the fatigue characteristics of the material intended for their manufacture.

2.3.15 A detailed weld specification where an impeller has welded blades.

2.3.16 Full details of the means of corrosion protection in the case of carbon or carbon manganese steel shafts. Alternatively, where it is proposed to use composite shafts, details of the connections at flanges, materials, resin, lay-up procedures, quality control procedures and documentary evidence of fatigue endurance strength are to be provided.

2.3.17 Dry impeller mass and polar moment of inertia.

2.3.18 The prime mover type and designation.

2.3.19 Details of the control engineering aspects of the system design, in accordance with *Vol 2, Pt 9, Ch 1 General Requirements for the Design and Construction of Electrotechnical Systems* & *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*.

2.3.20 The tolerance specification, agreed between the manufacturer and the Shipbuilder or Owner, to which the components of the unit are to be manufactured, is to be defined together with a justification.

2.3.21 Details of the water jet's loading reactions, together with the positions of application within the hull; they are to include the maximum applied thrust, tunnel pressures, moments and forces imposed on the ship.

2.3.22 The water jet unit's rated flow and head.

2.3.23 Where an engineering and safety justification report is required, the following supporting information is to be submitted:

- A Risk Assessment (RA), *see Vol 2, Pt 4, Ch 2, 2.4 Risk Assessment (RA)*.
- Design standards and assumptions.
- Limiting operating parameters.
- A statement and evidence in respect of the anticipated reliability of any non-duplicated components.

2.3.24 Recommended installation, inspection, maintenance and component replacement procedures. These are to include any in-water engineering procedures, where recommended by the water jet manufacturer.

2.3.25 All transient loads which the steering unit is likely to experience from manoeuvring, accelerating, decelerating and the sea conditions.

2.4 Risk Assessment (RA)

2.4.1 A Risk Assessment in accordance with *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)* is to be carried out where a single water jet system is the ship's sole means of propulsion, *see Vol 2, Pt 4, Ch 2, 2.2 Documentation required for design review 2.2.3*. The RA is to identify components where a single failure could cause the loss of all propulsion and/or steering capability and the proposed arrangements for preventing and mitigating the effects of such a failure.

■ Section 3 Design requirements

3.1 General

3.1.1 The arrangement of water jet units is to be such that the ship can be satisfactorily manoeuvred to a declared performance capability. The operating conditions covered are to include the following:

(a) Maximum continuous shaft power/speed to the impeller in the ahead condition at the declared steering angles and conditions.
(b) Manoeuvring speeds of the impeller shaft and/or reversing mechanism in the ahead and astern direction at the declared steering angles and sea conditions.
(c) The ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manoeuvring conditions, and so bring the ship to rest from maximum service speed. Results of the trials are to be recorded.
(d) Astern running conditions for the ship.

3.1.2 The mean loadings are those loadings induced by the water jet absorbing the mean torque supplied by the prime mover.

3.1.3 Fluctuating loads are defined as those loads which occur during one revolution of the impeller due to cyclic variations. For example, the spatial flow variations and torsional vibration at nominally steady state operating conditions.

3.1.4 Transient loads are defined as those loadings resulting from acceleration and deceleration of the ship, manoeuvring, seaway conditions and other similar forms of loading. This also includes any significant back-pressure effects developed from the operation of the reversing bucket, if fitted.

3.1.5 To ensure self-priming of the water jet unit, the shaft centreline of the unit is to be lower than the light draught static waterline of the ship. In cases where this is either impracticable or undesirable, the distance of the impeller shaft centreline above the ship's light draught waterline is to be less than or equal to 10 per cent of the pump inlet diameter.

3.1.6 Provision is to be made to allow for the in-service visual inspection of the complete blade surfaces of both the impeller and stator blades, using either a direct visual or borescope inspection technique.

3.2 Shaftline

3.2.1 The diameter of the shaftline components is to comply with *Vol 2, Pt 3, Ch 2 Shafting Systems*. For calculation purposes, the shaft carrying the impeller is to be taken as equivalent to a screwshaft.

3.2.2 Where it is proposed to use carbon or carbon manganese steel shafts which may be in contact with sea-water, these are to be protected.

3.2.3 The diameter of unprotected screwshafts of corrosion-resistant material is not to be less than that given in *Vol 2, Pt 3, Ch 2, 4.4 Screwshafts and tube shafts 4.4.7*.

3.2.4 The use of composite shafts is permitted, *see Vol 2, Pt 4, Ch 2, 2.3 Calculations and information 2.3.16*.

3.2.5 Where lengths of shafts are joined using couplings of the shrunk element type, a factor of safety, based upon the mean plus the vibratory and transient torques, against slippage of 2,0 is to be achieved for couplings which are located inboard and 2,5 for couplings which are located outboard.

3.2.6 Where shaftline components are bolted together, a factor of safety of 1,5 is to be achieved for the design of the bolted connection when considered in the context of the mean, fluctuating and transitory loadings.

3.2.7 If a keyed fitting of the impeller to the shaft is contemplated, the requirements of *Vol 2, Pt 3, Ch 2, 4.12 Keys and keyways for propeller connections* are to be satisfied.

3.2.8 Where it is proposed to fit a keyless impeller, the fitting is to comply with the requirements of *Pt 5, Ch 7, 3.2 Keyless propellers* of the Rules and Regulations for the Classification of Ships, as applicable, excluding the requirements for Ice Class. Use of the words 'propeller' and 'screwshaft' are to be taken as meaning 'impeller' and 'impellershaft', respectively.

3.3 Shaft support system and guide vanes

3.3.1 In cases where the shaft requires support from the tunnel walls ahead of the impeller or, alternatively, where guide vanes are required to assist the flow around a bend in the ducting system, the supports or guide vanes are to be suitably aligned to the flow and have suitably rounded leading and trailing edges or be of an aerofoil section.

3.3.2 In general, the fillet radius should be greater than or equal to the maximum thickness of the vane or support at that location. Smaller radii may be considered, for which the results of an approved measurement programme or calculation procedure are to be submitted. In all cases, a factor of safety of at least 1,5 is to be demonstrated for the maximum designed operating conditions.

3.3.3 A facility for the inspection of the supports or guide vanes is to be provided which will allow either direct visual or borescope inspection of these components and their transition to other members.

3.4 Impeller

3.4.1 A calculation to determine the stresses within the impeller blades is to be carried out, which takes into account the mean blade loading, fluctuating loadings, transient loads and centrifugal force. The computations may be accomplished by either classical methods or numerical analysis. Designs of water jet systems which have been based on a combination of computational fluid dynamics and finite element methods will be considered. However, it will be necessary to demonstrate to the satisfaction of LR that the formulation of the methods used has been correlated with previous full scale measurement or other calculation experience.

3.4.2 For the purposes of the calculation required by this sub-Section, the fluctuating stresses during one revolution of the impeller are to be taken as 20 per cent of the maximum mean stress, and the stresses from transient loadings are to be taken as 15 per cent of the hydrodynamic mean stress, unless otherwise specified by the designer.

3.4.3 The fatigue assessment of the impeller blades is to be based on the stress in the root sections, excluding the influence of the blade root fillets. This assessment is to include the following components:

- the maximum stresses derived from the mean loading, including both the hydrodynamic and centrifugal components;
- the amplitude of the fluctuating stresses during one revolution of the impeller;
- the stresses derived from transient loading and an allowance for any residual stresses in the material.

It is permissible to combine the variable components of stress in a linear fatigue damage accumulation assessment procedure. A factor of safety of at least 1,5 against fatigue failure is to be demonstrated for the maximum continuous rating condition or any other more onerous condition, *see Vol 2, Pt 4, Ch 2, 3.1 General 3.1.1*.

3.4.4 In general, the fillet radius is to be greater than the maximum thickness of the impeller blade at that location. Composite radiused fillets or elliptical fillets which provide an improved stress concentration factor are preferred.

3.4.5 Where an impeller has bolted-on blades, consideration is to be given to the distribution of stress in the palms of the blade and in the boss and bolting arrangements.

3.4.6 Where an impeller has welded blades, the welds are to be of the full penetration type or of equivalent strength. Where laser welding is to be used, details are to be submitted for consideration.

3.4.7 The blades are to be provided with hydrodynamically faired leading and trailing edges which may be either of simple radius or of a more complex aerofoil edge form. The tip clearance, whilst being kept to a minimum for hydrodynamic purposes, is to be sufficient to allow for any transient vibrational behaviour, axial shaft movement or differential thermal expansion.

3.4.8 A calculation of the blade natural frequency for the impeller blades is to be undertaken. The fundamental natural frequency in water of the blade is to be shown to lie outside any expected excitation frequencies within a speed range of the water jet unit and up to 10 per cent above the maximum impeller speed.

3.5 Stator

3.5.1 The stator blades, where fitted, are to be designed to be capable of withstanding the combined hydrodynamic mean, fluctuating, transient and mechanical loads, including any loads transmitted via shaft bearings, developed by the unit and reacted through the blades when the impeller is absorbing full power. Consideration is to be given to situations when the vessel is either free running or in a condition specified by *Vol 2, Pt 4, Ch 2, 3.1 General 3.1.1* or undergoing stopping, accelerating or decelerating manoeuvres. A factor of safety against mechanical failure by yielding of the blades of 1,5 is to be demonstrated.

3.5.2 In general, the fillet radius is to be greater than the maximum thickness of the blade at that location. Composite radiused fillets or elliptical fillets which provide improved stress concentration factors are preferred.

3.5.3 If the stator ring comprises a segmented assembly, consideration is also to be given to the distribution of stress in the various adjacent members of the overall assembly.

3.5.4 A calculation of the relative blade-passing frequency between the rotor and stator blades is to demonstrate that this does not coincide with the natural frequency of the stator blades over the speed range of the water jet unit and up to 10 per cent above maximum impeller speed.

3.5.5 The stator blades are to be provided with hydrodynamically faired leading edges which may have either a simple radius or a more complex aerofoil edge form.

3.5.6 Where the stator blading assembly forms part of the nozzle, the requirements of *Vol 2, Pt 4, Ch 2, 3.7 Nozzle/steering arrangements* are to be considered in association with those for the stator assembly.

3.6 Tunnel and securing arrangements

3.6.1 The tunnel is to be adequately supported, framed and fully integrated into the hull structure. The critical locations and integrity of the supports and framing are to be as specified in the Risk Assessment, see *Vol 2, Pt 4, Ch 2, 2.4 Risk Assessment (RA) 2.4.1*, and agreed by the Shipbuilder and LR.

3.6.2 The tunnel and supporting structure scantlings are to be not less than the Rule requirements for the surrounding structure. The strength of the hull structure in way of tunnel(s) is to be maintained. The structure is to be adequately reinforced and compensated as necessary. All openings are to be suitably reinforced and have radiused corners.

3.6.3 Consideration is to be given to providing the inlet to the tunnel with a suitable guard to prevent the ingress of large objects into the rotodynamic machinery. The dimensions of this guard, if fitted, are to strike a balance between undue efficiency loss due to flow restriction and viscous losses, the size of object allowed to pass and the susceptibility to clog with weed and other flow-restricting matter.

3.6.4 The inlet profile of the tunnel is to be designed so as to provide a smooth uptake of the water over the range of vessel operating trims and avoid significant separation and/or cavitation of the flow which may then pass downstream into the rotating machinery.

3.6.5 Design consideration is to take account of pressures which could develop as a result of a duct blockage, as well as in relation to the axial location of rotating parts.

3.6.6 The strength of the tunnel and supporting structure is to be examined by direct calculation procedures.

3.7 Nozzle/steering arrangements

3.7.1 In general, the steering systems and components are to comply with the requirements of *Vol 2, Pt 6, Ch 1 Steering Gear*. The requirements of *Vol 2, Pt 6, Ch 1, 4.1 General 4.1.3* and *Vol 2, Pt 6, Ch 1, 4.1 General 4.1.3* are addressed by *Vol 2, Pt 4, Ch 2, 3.7 Nozzle/steering arrangements 3.7.3* and the requirements of *Vol 2, Pt 6, Ch 1, 4.1 General 4.1.3* and *Vol 2, Pt 6, Ch 1, 4.1 General 4.1.3* are addressed by *Vol 2, Pt 4, Ch 2, 3.7 Nozzle/steering arrangements 3.7.4*.

3.7.2 For vessels with more than one steerable water jet, the requirement for auxiliary steering arrangements in *Vol 2, Pt 6, Ch 1 Steering Gear* is to be achieved by equipping each of the steerable water jets with its own dedicated and independent steering gear control system and power actuating system. Consideration will be given to alternative arrangements providing equivalence can be demonstrated.

3.7.3 The main steering arrangements are to be operated by power and capable of changing the direction of the ship's water jet nozzles from one side to the other at declared steering angle limits, at an average rotational speed of not less than 0,4 rev/min with the ship running ahead at maximum ahead service speed.

3.7.4 The auxiliary steering arrangements are to be:

3.7.5 Capable of changing the direction of the ship's water jet nozzles from one side to the other at declared steering angle limits at an average rotational speed of not less than 0,083 rev/min, with the ship running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater.

3.7.6 Operated by power for ships having propulsion power of more than 2500 kW per water jet unit and for all ships, where it is necessary, to meet the requirements of *Vol 2, Pt 4, Ch 2, 3.7 Nozzle/steering arrangements 3.7.5*.

3.7.7 Nozzles can be either of a fixed or steerable form. The design of the nozzle is to take into account fully the change in pressure distribution along its inner surface, together with the other mechanical loads (e.g. stator assembly loads) and transient loads caused by the flow directing attachments which may be reacted through the body of the nozzle. In this analysis, the changes to the pressure distribution caused by transient manoeuvres are to be considered.

3.7.8 In addition to the requirements of *Vol 2, Pt 6, Ch 1 Steering Gear*, the steering mechanism and bucket are to be capable of maintaining the manoeuvrability of the ship in terms of turning circle, zig-zag and stopping requirements within the limits defined by IMO *Resolution MSC.137(76) - Standards for Ship Manoeuvrability - (adopted on 4 December 2002)*.

3.7.9 Consideration is to be given to all transient loads which the steering unit is likely to experience from manoeuvring, accelerating, decelerating and the sea conditions.

3.7.10 The nozzle/bucket is to be given mechanical protection by the Shipbuilder from other impact damage such as collision.

3.8 Bolts

3.8.1 Detailed consideration and analysis are to be given to essential bolting arrangements in critical locations, as specified in the Risk Assessment, *see Vol 2, Pt 4, Ch 2, 2.4 Risk Assessment (RA) 2.4.1*, and where indicated by the manufacturer or Shipbuilder and agreed by LR. These are to include bolts used in the securing of blades or guide vanes, assembly of the unit in the ship and any conduit components.

■ *Section 4*
Piping systems

4.1 General

4.1.1 The piping systems for a water jet unit are to comply with the general requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements*.

4.1.2 Lubricating and hydraulic oil systems and standby arrangements are to comply with the requirements of *Vol 2, Pt 7, Ch 3 Machinery Piping Systems*; in addition, steering hydraulic systems are to comply with the applicable requirements of *Vol 2, Pt 6, Ch 1 Steering Gear*.

■ *Section 5*
Control and monitoring

5.1 General

5.1.1 In addition to this Section, the control engineering systems are to comply with *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*.

5.1.2 For water jets used as the only means of propulsion and steering, a standby or alternative power source for the actuating device that controls the angular position and/or the reversing angle is to be provided. Automatic start of the standby pump supplying hydraulic power for steering and reversing is to be provided.

5.1.3 Means are to be provided at each control station to stop each water jet.

5.2 Monitoring and alarms

5.2.1 In addition to the requirements of *Vol 2, Pt 6, Ch 1 Steering Gear*, alarms and monitoring requirements are indicated in *Vol 2, Pt 4, Ch 2, 5.2 Monitoring and alarms 5.2.2* and *Table 2.5.1 Alarms*.

Table 2.5.1 Alarms

Item	Alarm	Note
Hydraulic system pressure	Low	—
Hydraulic oil supply tank level	Low	—
Lubricating oil temperature	High	—

Lubricating oil pressure	Low	In forced lubrication systems
Lubricating oil tank level	Low	Where a tank is provided
Ratio of jet rpm/vessel speed	High	Only if installed power per jet > 4 MW
Control system failure	Fault	Includes follow-up failure of steering or reversing system

5.2.2 An indication of the angular position of the nozzle is to be provided at each station from which it is possible to control the direction of thrust from the units.

5.2.3 An indication of both the required and actual reversing bucket position is to be provided at each station from which it is possible to control the reversal of thrust.

5.2.4 All alarms associated with water jet unit faults are to be indicated individually at the control stations and in accordance with the alarm system specified by *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*.

■ *Section 6* Electrical systems

6.1 Installation and distribution arrangements

6.1.1 The electrical installation is to comply with the relevant sections of *Vol 2, Pt 9 Electrotechnical Systems*.

6.1.2 Water jet auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as practicable and without the use of common feeders, transformers, converters, protective devices or control circuits.

■ *Section 7* Inspection, testing and fitting of water jets

7.1 General

7.1.1 The finished impeller is to be statically balanced on completion of the manufacturing process, and is to meet the requirements of ISO 1940 Grade G6,3 or an alternative Standard acceptable to LR. In the case where the blade tip speed is greater than 60 m/s, dynamic balancing is required, unless otherwise agreed by the manufacturer and LR.

7.1.2 The following tests, markings and inspections are to be carried out in the presence of the Surveyor:

(a) The balancing of the impeller or the blades.
(b) Non-destructive examination of the impeller blades and the principal component parts of the propulsion system; *see Ch 4, 8 Stainless steel castings* for austenitic stainless steels and *Ch 8, 3 Aluminium alloy castings* for aluminium alloys of the *Rules for the Manufacture, Testing and Certification of Materials*.
(c) The quality of the fit of the impeller boss on the shaft taper.
(d) The fitting of the impeller to the shaft and its subsequent functional testing.
(e) The finished surfaces of the impeller boss, conical bores, fillets, cones and blade surfaces are to be shown to conform to the tolerances specified on the impeller drawing.

7.1.3 Bolts and nuts in critical locations, as specified in the Risk Assessment, *See Vol 2, Pt 4, Ch 2, 2.4 Risk Assessment (RA) 2.4.1* and, where indicated by the manufacturer or Shipbuilder and agreed by LR, are to be equipped with adequate securing arrangements to the satisfaction of the LR Surveyor.

7.2 Shop tests and installation of water jet systems

7.2.1 The completed water jet unit is to undergo a tightness test in which an internal hydrostatic pressure of 1,5 bar above the maximum working pressure of the unit is to be applied.

7.2.2 In cases where the impeller is fitted to the shaft using an interference fit, the bedding of the impeller with the shaft is to be demonstrated in the shop to the satisfaction of the LR Surveyor. Sufficient time is to be allowed for the temperature of the components to equalise before bedding. A contact marking between the bore of the impeller boss and the shaft surface of better than 80 per cent is to be demonstrated when the contact marking ink is spread thinly on the surface of the shaft. Alternative means for demonstrating the bedding of the impeller will be considered.

7.2.3 Means are to be provided to indicate the relative axial position of the impeller boss on the shaft. Permanent reference marks are to be made on the impeller boss, shaft and any nut to indicate angular and axial positioning of the impeller. Care is to be taken in marking the inboard end of the shaft taper to minimise stress-raising effects.

7.2.4 A copy of the fitting curve, relative to temperature, and means for determining any subsequent movement are to be placed on board.

7.2.5 The impeller running clearances are to be checked following the installation of the unit in the ship.

7.2.6 The thrust bearing clearances in the water jet system are to be verified against the required design values. This is to be done following the installation of the unit in the ship.

7.2.7 The piping systems are to be adequately flushed in accordance with the manufacturer's recommendations and the final levels of contamination recorded. Similarly, pressure testing of the piping systems is to comply with *Vol 2, Pt 7, Ch 1 Piping Design Requirements*.

7.3 Sea trial requirement

7.3.1 The following requirements are to be complied with:

- *Vol 2, Pt 1, Ch 3, 16 Sea trials* for sea trials.
- *Vol 2, Pt 1, Ch 3, 15.4 Testing* for steering trials.

In addition, the general design capability specified in *Vol 2, Pt 4, Ch 2, 3.1 General 3.1.1* is to be demonstrated to the Surveyor's satisfaction.

7.3.2 The control systems relating to the correct functioning of the water jet are to be the subject of harbour and then sea trials. Demonstration of the requirements of *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems* is required and the design combinations of control functions are to be undertaken during the trials programme.

7.3.3 On sea trials and under free running conditions, the relationship between ship speed and impeller rotational speed is to be verified against the water jet's design basis.

7.3.4 Any trials and testing identified from the Risk Assessment report are to be carried out, *see Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*.

■ *Section 8*
Installation, maintenance and replacement

8.1 General

8.1.1 All water jet system propulsion units are to be provided with a copy of the manufacturer's installation and maintenance manual that is pertinent to the actual equipment. *See Vol 2, Pt 4, Ch 2, 2.3 Calculations and information 2.3.24*.

8.1.2 The manual required by *Vol 2, Pt 4, Ch 2, 8.1 General 8.1.1* is to be placed on board and is to contain the following information:

(a) Description of the water jet propulsion system with details of function and design operating limits. This is also to include details of support systems such as lubrication, cooling and condition monitoring arrangements.
(b) Identification of all components together with details of any that have a defined maximum operating life.
(c) Instructions for installation of the system on board ship, with details of any required specialised equipment.

(d) Instructions for commissioning at initial installation and following maintenance.

(e) Maintenance and service instructions to include inspection/ renewal of bearings and sealing arrangements. This is also to include component fitting procedures, clearance measurements and lubricating oil treatment, where applicable.

(f) Actions required in the event of fault/failure conditions being detected.

(g) Precautions to be taken by personnel working during installation and maintenance.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the requirements for Machinery and Engineering Systems in *Vol 2, Pt 1, Ch 1 General Requirements for Classification of Engineering Systems* and *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*

1.1.2 This Chapter gives requirements for fixed or steerable thruster units (azimuth thrusters) which are used for propulsion and steering, and also applies to transverse propulsion (tunnel) thrusters which are an aid to manoeuvring.

1.1.3 In this Chapter where the dimensions of any particular component are determined from shaft power, *P*, in kW, and revolutions per minute, *R*, the values to be used are those defined in *Vol 2, Pt 1, Ch 3, 4.3 Power ratings*

1.2 Redundancy

1.2.1 A minimum of two azimuth thruster units is to be provided where these form the sole means of propulsion. Where a single azimuth thruster installation is proposed, it will be subject to consideration, taking into account the proposed restricted area notation.

1.2.2 For vessels with multiple azimuthing thrusters, the requirement for auxiliary steering arrangements in *Vol 2, Pt 6, Ch 1, 4 Performance* is to be achieved by equipping each of the azimuthing thrusters with its own dedicated and independent steering gear control system and power actuating system. Consideration will be given to alternative arrangements providing equivalence can be demonstrated.

1.2.3 The failure of one azimuth thruster unit or its control system is not to render any other thruster inoperative.

1.3 Inclination of ship

1.3.1 Thruster units are to operate satisfactorily under the conditions as shown in *Vol 2, Pt 1, Ch 3, 4.3 Power ratings*

■ *Section 2* Documentation required for design review

2.1 Submission of information

2.1.1 At least three copies of the following plans and information as detailed in *Vol 2, Pt 4, Ch 3, 2.2 Plans* and *Vol 2, Pt 4, Ch 3, 2.3 Calculations and specifications* are to be submitted.

2.2 Plans

2.2.1 **Fixed/Azimuth propulsion thrusters**

(a) A general arrangement sectional assembly plan showing all the connections of the torque transmitting components from the prime mover to the propeller, together with the azimuthing mechanism and, if a nozzle is provided, the nozzle ring structure and nozzle support struts.
(b) Detailed and dimensional plans of the individual torque transmitting components.
(c) Schematic plans of lubricating and hydraulic systems, together with pipe material, relief valves and working pressures.

2.2.2 **Tunnel thrusters**

Structural assembly plan including connections to tunnel.

2.3 Calculations and specifications

2.3.1 **Fixed/Azimuth propulsion thrusters** A System Design Description (*see Vol 2, Pt 1, Ch 3, 3.5 System design description*) containing the following:

(a) Thruster prime mover type and operational power/speed envelope.
(b) Rating and type of motor for the azimuthing mechanism (e.g. type – hydraulic or electric).
(c) Gearing calculations for the azimuthing mechanism which is to be designed to a recognised National Standard.
(d) Bearing specifications.
(e) Details of control engineering aspects in accordance with *Vol 2, Pt 9, Ch 1 General Requirements for the Design and Construction of Electrotechnical Systems* & *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*.
(f) Calculations indicating suitability of components for short-term high power operation, where applicable. *See Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*
(g) Where carried out in accordance with *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*, a fatigue strength analysis of components indicating a factor of safety of 1,5 at the design loads, based on a suitable fatigue failure criteria.

2.3.2 **Tunnel thrusters**

A System Design Description (*see Vol 2, Pt 1, Ch 3, 3.5 System design description*) detailing the gears, shafts, couplings and propeller, stock and struts, the thruster prime mover type and the operational power/speed envelope.

■ *Section 3* Materials

3.1 Azimuth thrusters

3.1.1 The materials used in the construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2015* .

■ *Section 4* Design and construction

4.1 General

4.1.1 The arrangement of all types of thrusters is to be such that the craft can be manoeuvred in accordance with the design specifications.

4.1.2 The requirements associated with the structural and watertight integrity and the installation arrangement are to be in accordance with *Vol 1, Pt 3, Ch 3 Ship Control Systems*

4.1.3 In addition to the requirements of this Section, reference is to be made to:

(a) Main transmission gearing, *Vol 2, Pt 3, Ch 1 Gearing*.
(b) Main transmission shafting, *Vol 2, Pt 3, Ch 2 Shafting Systems*.
(c) Propelle,r *Vol 2, Pt 4, Ch 1 Propellers*.
(d) Torsional vibration, *Vol 2, Pt 5, Ch 1 Torsional Vibration*.
(e) Lateral vibration for shafting systems which include cardan shafts, *Vol 2, Pt 5, Ch 3 Lateral Vibration*.
(f) Steering arrangements, *Vol 2, Pt 6, Ch 1 Steering Gear*.

4.2 Azimuth thrusters

4.2.1 The following requirements are to be complied with:

(a) In general, the steering systems and components are to comply with the requirements of *Vol 2, Pt 6, Ch 1 Steering Gear*. The requirements of *Vol 2, Pt 6, Ch 1, 4.1 General 4.1.2* and *Vol 2, Pt 6, Ch 1, 4.1 General 4.1.2* are addressed by *Vol 2, Pt 4, Ch 3, 4.2 Azimuth thrusters 4.2.1* and the requirements of *Vol 2, Pt 6, Ch 1, 4.1 General 4.1.3* and *Vol 2, Pt 6, Ch 1, 4.1 General 4.1.3* are addressed by *Vol 2, Pt 4, Ch 3, 4.2 Azimuth thrusters 4.2.1*.
(b) The steering arrangements for azimuthing thrusters used for dynamic positioning applications with an associated class notation are to be capable of a maximum rotational speed of not less than 1,5 rev/min.
(c) The main steering arrangements are to be operated by power and capable of changing the direction of the ship's azimuth thrusters from one side to the other at declared steering angle limits, at an average rotational speed of not less than 0,4 rev/min with the ship running ahead at maximum ahead service speed.
(d) The auxiliary steering arrangements are to be:
    (i) Capable of changing the direction of the ship's azimuth thrusters from one side to the other at declared steering angle limits at an average rotational speed of not less than 0,083 rev/min with the ship running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater.
    (ii) Operated by power for ships having propulsion power of more than 2500 kW per thruster unit and for all ships, where it is necessary, to meet the requirements of *Vol 2, Pt 4, Ch 3, 4.2 Azimuth thrusters 4.2.1*.
(e) Gearing for the azimuthing mechanism is to be designed to a recognised National Standard. The design is to consider both static ($<10^3$ cycles) and dynamic loading conditions.
(f) Under dynamic operating conditions, the gear is to be considered for:
    (i) design maximum dynamic duty steering torque;
    (ii) variable loading, where applicable. A spectrum (duty) factor may be used. The load spectrum value is to be derived using load measurements of similar units, where possible.
(g) Under a static duty ($<10^3$ load cycles) steering torque, which should be not less than M_T, as defined in *Vol 2, Pt 4, Ch 3, 4.3 Azimuth thrusters with a nozzle 4.3.1*
(h) The following minimum factor of safety values are to be achieved:

    Surface Stress S_{Hmin} = 1,0.

    Bending Stress S_{Fmin} = 1,5.
(i) For hydraulic pressure retaining parts and load bearing components, *see also Vol 2, Pt 6, Ch 1 Steering Gear*

4.3 Azimuth thrusters with a nozzle

4.3.1 Where the propeller is contained within a nozzle, the equivalent rudder stock diameter in way of tiller, used in *Table 3.2.12 Rudder couplings to stock* in Vol 1, Pt 3, Ch 3, is to be determined as follows:

$$d_{su} = 26,03\sqrt[3]{(V+3)^2 A_N X_{PF}} \text{ mm}$$

where

V = maximum service speed, in knots, which the craft is designed to maintain under thruster operation

A_N = projected nozzle area, in m^2, and is equal to the length of the nozzle multiplied by the mean external vertical height of the nozzle

X_{PF} = horizontal distance from the centreline of the steering tube to the centre of pressure, in metres. The position of the centre of pressure is determined from *Table 3.2.7 Single plate rudder construction* in *Vol 1, Pt 3, Ch 3 Ship Control Systems*

The corresponding maximum turning moment, M_T, is to be determined as follows:

M_T = 11,1 x d_{SU}^3 Nmm.

4.3.2 In addition to the requirements of *Vol 1, Pt 3 Design Principles and Constructional Arrangements* the scantlings of the nozzle stock or steering tube are to be such that the section modulus *Z* against transverse bending at any section x–x is not less than:

$$Z = 1,73\sqrt{(V+3)^4 A_N^2 X_{PF}^2 + \frac{a^2}{4} T_M^2 10^4}\ \mathrm{cm}^3$$

where

a = dimension, in metres, as shown in *Figure 3.4.1 Azimuth thruster*

T_M = maximum thrust of the thruster unit, in tonnes.

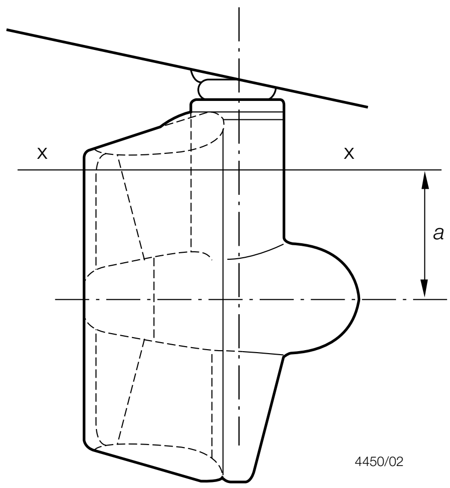


Figure 3.4.1 Azimuth thruster

4.3.3 The scantlings of nozzle connections or struts will be specially considered. In the case of certain high powered ships, direct calculation may be required.

4.3.4 Where the propeller is not contained in a nozzle, the scantlings in way of the tiller will be subject to special consideration.

■ Section 5
Piping systems

5.1 General

5.1.1 The piping system for azimuth thrusters is to comply with the general design requirements given in *Vol 2, Pt 7, Ch 1 Piping Design Requirements*

5.1.2 The specific requirements for lubricating/hydraulic oil systems and standby arrangements are given in *Vol 2, Pt 7, Ch 3 Machinery Piping Systems*

5.2 Azimuth thruster

5.2.1 The hydraulic power operating systems for each azimuth thruster are to be provided with the following:

(a) arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system;

(b) a fixed storage tank having sufficient capacity to recharge at least one azimuth power actuating system including the reservoir. The piping from the storage tank is to be permanent and arranged in such a manner as to allow recharging from within the thruster space.

5.2.2 Where the lubricating oil for the azimuth thrusters is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the thruster or reducing the supply of filtered oil.

■ *Section 6*
Control and monitoring

6.1 General

6.1.1 Except where indicated in this Section, the control engineering systems are to be in accordance with *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*

6.1.2 Azimuthing control for azimuth thruster(s) and propeller pitch control for azimuth and/or tunnel thruster(s) are to be provided from the navigating bridge, the main machinery control station and locally.

6.1.3 Means are to be provided at the remote control station(s) to stop each azimuth or tunnel thruster unit.

6.2 Monitoring and alarms

6.2.1 Alarms and monitoring requirements are indicated in *Vol 2, Pt 4, Ch 3, 6.2 Monitoring and alarms 6.2.2*, *Vol 2, Pt 4, Ch 3, 6.2 Monitoring and alarms 6.2.3* and *Table 3.6.1 Alarms*

6.2.2 An indication of the angular position of the azimuth thruster(s), the direction of thrust, an indication representative of the magnitude of thrust and an indication of the propeller pitch position for azimuth and/or tunnel thruster(s) are to be provided at each station from which it is possible to control the direction of thrust or the pitch.

Table 3.6.1 Alarms

Item	Alarm	Note
Thruster, azimuth or tunnel	—	Indicators, *see Vol 2, Pt 4, Ch 3, 6.2 Monitoring and alarms 6.2.2*
Azimuthing motor	Power failure, single phase	Also running indication on bridge and at machinery control station
Propeller pitch motor	Power failure	Also running indication on bridge and at machinery control station
Propulsion motor	Overload, power failure	Also running indication on bridge and at machinery control station
Control system power	Failure	
Hydraulic oil supply tank level	Low	
Hydraulic oil system pressure	Low	
Hydraulic oil system temperature	High	Where oil cooler is fitted
Hydraulic oil filters differential pressure	High	Where oil filters are fitted
Lubricating oil supply pressure	Low	If separate forced lubrication

6.2.3 The alarms described in *Table 3.6.1 Alarms* are to be indicated individually on the navigating bridge and in accordance with the alarm system specified by *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*

■ *Section 7* **Electrical systems**

7.1 General

7.1.1 The electrical installation is to be designed, constructed and installed in accordance with the requirements of *Vol 2, Pt 4, Ch 3, 7.2 General arrangements*.

7.1.2 Where the thruster units are electrically driven, the relevant requirements, including surveys, of *Vol 2, Pt 9 Electrotechnical Systems* are to be complied with.

7.2 General arrangements

7.2.1 Where a central power generation system is employed, the requirements of *Vol 2, Pt 4, Ch 5, 4.3 Power requirements 4.3.5* are to be complied with.

7.2.2 For azimuth thrusters, the generating and distribution system is to be so arranged that after any single failure, steering capability can be maintained or regained within a period not exceeding 45 seconds, and the effectiveness of the steering after such a fault will not be reduced by more than 50 per cent. This may be achieved by the parallel operation of two or more generating sets, or alternatively when the electrical requirements may be met by one generating set in operation, on loss of power, the automatic starting and connecting to the switchboard of a standby set, provided that this set can restart and run a thruster with its auxiliaries.

7.2.3 The failure of one thruster unit or its control system is not to render any other thruster inoperative.

7.3 Distribution arrangements

7.3.1 Azimuth thruster auxiliaries and controls are to be served by individual circuits. Services that are duplicated are to be separated throughout their length as widely as is practicable and without the use of common feeders, transformers, converters, protective devices or control circuits.

7.4 Auxiliary supplies

7.4.1 Where the auxiliary services and thruster units are supplied from a common source, the following requirements are to be complied with:

(a) the voltage regulation and current sharing requirements defined in *Vol 2, Pt 9, Ch 2, 6.4 Generator control 6.4.2* and *Vol 2, Pt 9, Ch 2, 6.4 Generator control 6.4.7* are to be maintained over the full range of power factors that may occur in services;
(b) auxiliary equipment and services are to operate with any waveform distortion introduced by converters without deleterious effect. (This may be achieved by the provision of suitably filtered/converted supplies).

■ *Section 1* Scope

1.1 Application

1.1.1 This Chapter applies to podded propulsion units where used for propulsion or as the sole means of steering.

1.1.2 For the purposes of these Rules, a podded propulsion unit is any propulsion or manoeuvring device that is external to the normal form of the ship's hull and houses a propeller powering device.

1.1.3 The requirements of this Chapter relate to podded propulsion units powered by electric propulsion motors (and are in addition to the requirements for Electric Propulsion in *Vol 2, Pt 4, Ch 5, 4 Electric propulsion systems* and other relevant Sections). Podded propulsion units with other drive arrangements will be subject to individual consideration.

1.1.4 The structural requirements stated in *Vol 2, Pt 4, Ch 4, 5.1 Pod structure*, *Vol 2, Pt 4, Ch 4, 5.2 Hull support structure* and *Vol 2, Pt 4, Ch 4, 5.3 Direct calculations* relate to podded propulsion units having a pod body with single supporting strut with or without an integral slewing ring arrangement, *see Figure 4.1.1 Podded propulsion unit*. Novel and unconventional arrangements will be subject to individual consideration. In such cases, the designers are advised to contact LR in the early stages of the design for advice on the manner and content of design information required for formal classification appraisal.

1.1.5 The aft end structures associated with podded installations are to be examined in respect of potential slamming with reference to *Vol 1, Pt 5, Ch 3, 4 Impact loads on external plating*.

1.1.6 It is the shipbuilder's responsibility to ensure that all installed equipment is suitable for operation in the location and under all anticipated environmental conditions associated with the design of the ship which is to include temperature, humidity, vibration and impulsive accelerations.

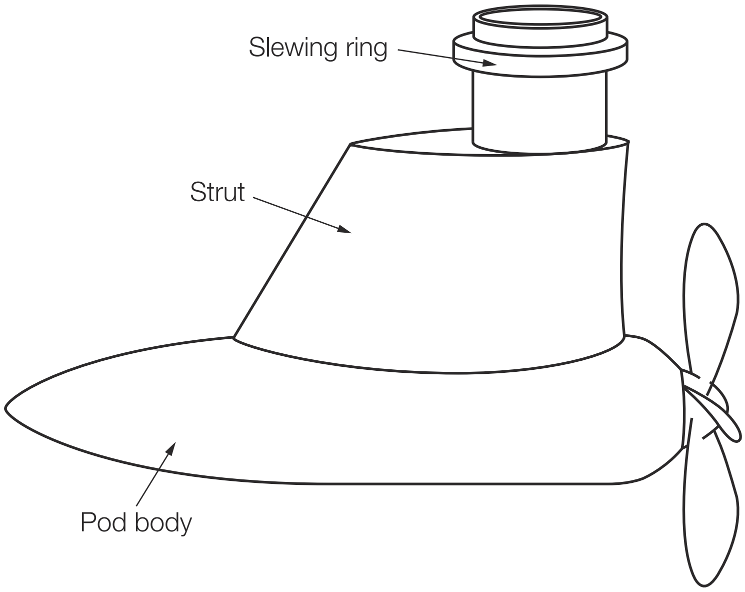


Figure 4.1.1 Podded propulsion unit

1.1.7 The design of a podded propulsor system is to take into account a range of operating conditions which are to include the following:

- All ahead sea-going conditions up to and including the maximum rated output of the podded propulsor while maintaining a steady course under foreseeable operating, sea and wind conditions and in cases where directional instability may occur.
- The ability of the ship to change direction rapidly at the declared steering angles with the ship running at maximum ahead service speed.
- Executing a steady turning manoeuvre with a tactical diameter not greater than 5*L* and advance not greater than 4,5*L* whilst maintaining a power corresponding to the test speed, where *L* is the length measured between the aft and forward perpendiculars. Test speed is defined as a speed of at least 90 per cent of the ship's speed corresponding to 85 per cent of the maximum rated power of the podded propulsor.
- Changing heading, manoeuvring in and out of harbour both ahead and astern, at slow speeds, stationary and starting from rest in foreseeable current and wind conditions.
- Berthing manoeuvres in the case of azimuthing podded propulsion units.
- Rapid acceleration and deceleration manoeuvres where the ship's operating profile demands this capability.
- Holding stationary positions over-ground under different conditions.
- Stopping manoeuvre as required by *Vol 2, Pt 9, Ch 11, 1.2 Trials*.
- Manoeuvring in ice where ice class is required.

■ *Section 2* **General requirements**

2.1 Pod arrangement

2.1.1 In general, for a ship to be assigned an unrestricted service notation, a minimum of two podded propulsion units is to be provided where these form the sole means of propulsion. For vessels where a single podded propulsion unit is the sole means of propulsion, an evaluation of a detailed engineering justification will be conducted by LR, *see Vol 2, Pt 4, Ch 4, 2.2 Documentation required for design review 2.2.2*. This evaluation process will include the appraisal of a Risk Assessment (RA) to verify that

sufficient levels of redundancy and monitoring are incorporated in the podded propulsion unit's support systems and operating equipment.

2.2 Documentation required for design review

2.2.1 In addition to the plans required by *Vol 2, Pt 3, Ch 1 Gearing* and *Vol 2, Pt 3, Ch 2 Shafting Systems*, *Vol 2, Pt 4, Ch 1 Propellers*, *Vol 2, Pt 5 Shaft Vibration and Alignment*, *Vol 2, Pt 6, Ch 1 Steering Gear*, *Vol 2, Pt 7, Ch 3 Machinery Piping Systems*and *Vol 2, Pt 9 Electrotechnical Systems* and *Vol 2, Pt 10 Human Factors*, the following plans and information are required to be submitted for appraisal. Where appropriate, the information shall be contained in a System Design Description document, *see Vol 2, Pt 1, Ch 3, 3.5 System design description*:

(a) Description of the ship's purpose/capabilities together with the pod's intended operational modes in support of these capabilities. The operational modes are to include stopping the vessel and restrictions on steering angles at different ship speeds. *See also Vol 2, Pt 4, Ch 4, 2.2 Documentation required for design review 2.2.1*.
(b) Power transmitted at MCR condition (shaft power and rpm) and other maximum torque conditions, e.g. bollard pull.
(c) Maximum transient thrust, torque and other forces and moments experienced during all envisaged operating modes as permitted by the steering and propulsor drive control systems.
(d) Details of the electric propulsion motor short-circuit torque and motor air gap tolerance.
(e) Sectional assembly in the Z-X plane, *see Figure 4.2.1 Pod co-ordinate system*.
(f) Specifications of materials and NDE procedures for components essential for propulsion and steering operation, to include propulsion shaft and slewing ring bearings, gearing and couplings, *see Vol 2, Pt 4, Ch 4, 4.1 General*.
(g) Details of the intended manoeuvring capability of the ship in each operating condition.
(h) Design loads for both the pod structure and propeller together with podded propulsion unit design operating modes,*see Vol 2, Pt 4, Ch 4, 2.4 Global loads 2.4.1*, *Vol 2, Pt 4, Ch 4, 6.3 Propulsion shafting 6.3.7*, *Vol 2, Pt 4, Ch 4, 6.6 Steering system 6.6.6* and *Vol 2, Pt 4, Ch 4, 6.6 Steering system 6.6.7*.
(i) Supporting data and direct calculation reports. This is to include, where applicable an assessment of anticipated global accelerations acting on the ship's machinery and equipment which may potentially affect the reliable operation of the propulsion system for all foreseeable seagoing and operating conditions. Typically, this may include response to slamming, extreme ship motions and pod interaction. *See also Vol 2, Pt 4, Ch 4, 1.1 Application 1.1.5*.
(j) Structural component details including: strut, pod body, bearing supports, bearing end caps, ship's structure in way of podded propulsion unit integration and a welding Table showing a key to weld symbols used on the plans specifying weld size, type, preparation and heat treatment. The information should include the following:

- Detailed drawings showing the structural arrangement, dimensions and scantlings.
- Welding and structural details.
- Connections between structural components (bolting).
- Castings' chemical and mechanical properties.
- Forgings' chemical and mechanical properties.
- Material grades for plate and sections.

(k) Nozzle structure, its support arrangements, together with related calculations for all foreseeable operating and seagoing conditions where the propeller operates in a nozzle (duct), *see Vol 1, Pt 3, Ch 3, 5 Fixed and steering nozzles, bow and stern thrust units, ducted propellers*.
(l) Propeller shaft bearing mounting and housing arrangement details, *see also Vol 2, Pt 4, Ch 4, 6.3 Propulsion shafting 6.3.6*.
(m) Details of propeller shaft and steering bearings, where roller bearings are used supporting calculations are to be submitted, *see Vol 2, Pt 4, Ch 4, 6.3 Propulsion shafting 6.3.7* and *Vol 2, Pt 4, Ch 4, 6.6 Steering system 6.6.7*.
(n) Propeller shaft seal details.
(o) Details of propeller shaft and pod steering securing/locking and means of aligning the securing/locking arrangements.
(p) Cooling systems piping system schematic.
(q) Details of any lubricating oil conditioning systems (filtering/cooling/heating) and control arrangements necessary to ensure the continuous availability of the required lubricating oil quality to the propeller shaft bearings.
(r) Details of installed condition monitoring equipment.
(s) Details of the derivation of any duty factor used in the design of the steering gears.
(t) Identification of any potentially hazardous atmospheric conditions together with details of how the hazard will be countered, this should include a statement of the maximum anticipated air temperature within the pod during full power steady state operation, *see Vol 2, Pt 4, Ch 4, 2.3 Pod internal atmospheric conditions*.
(u) Where provided, access and closing arrangements for pod unit inspection and maintenance.

(v) Heat balance calculations for the pod unit taking into account electrical thermal rises when the pod is operating at maximum continuous operating conditions, heat transfer and maximum sea-water/air temperatures, *see Vol 2, Pt 4, Ch 4, 6.7 Ventilation and Cooling Systems 6.7.4*.

(w) Details of proposed testing and trials required by *Vol 2, Pt 4, Ch 4, 9 Testing and trials*.

(x) Details of emergency steering and pod securing arrangements, *see Vol 2, Pt 4, Ch 4, 6.3 Propulsion shafting 6.3.11*.

(y) Quality plan for electronic control systems and electrical actuating systems.

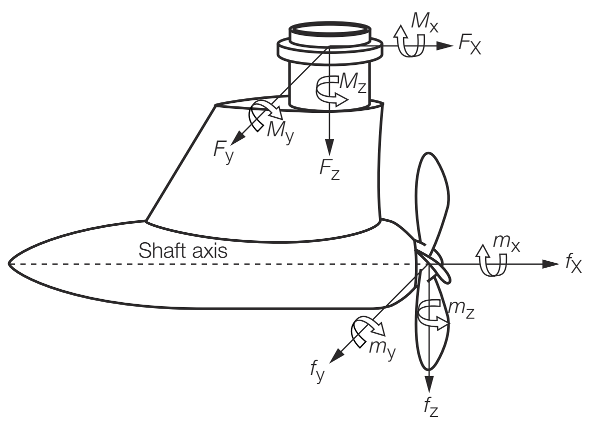


Figure 4.2.1 Pod co-ordinate system

2.2.2 Where an engineering justification report is required, the following supporting information is to be submitted:

- A Risk Assessment (RA) in accordance with *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)* is to be carried out, *see Vol 2, Pt 4, Ch 4, 2.1 Pod arrangement 2.1.1*. The RA is to identify components where failure could cause loss of all propulsion, steering capability or other Mobility systems or Ship Type systems, and the proposed arrangements for preventing and mitigating the effects of such a failure.
- Design standards and assumptions.
- Limiting operating parameters.
- A statement and evidence in respect of the anticipated reliability of any components.

2.2.3 Recommended installation, inspection, maintenance and component replacement procedures, *see also Vol 2, Pt 4, Ch 4, 5.1 Pod structure 5.1.2*. This is to include any in-water/underwater engineering procedures where recommended by the pod manufacturer. *See also Vol 2, Pt 4, Ch 4, 6.5 Bearing lubrication system 6.5.7* and *Vol 2, Pt 4, Ch 4, 10 Installation, maintenance and replacement procedures*.

2.3 Pod internal atmospheric conditions

2.3.1 Machinery and electrical equipment installed within the pod unit are to be suitable for operation, without degraded performance, at the maximum anticipated air temperature and humidity conditions within the pod unit with the pod operating at its maximum continuous rating in sea water of not less than 32°C after steady state operating conditions have been achieved.

2.3.2 Precautions are to be taken to prevent as far as reasonably practicable the possibility of danger to personnel and damage to equipment arising from the development of hazardous atmospheric conditions within the pod unit. Circumstances that may give rise to these conditions are to be identified and the counter measures taken are to be defined.

2.4 Global loads

2.4.1 The overall strength of the podded propulsion unit structure is to be based upon the maximum anticipated inservice loads, including, the effects of ship manoeuvring and of ship motion, *see Table 3.2.1 Ship motions* in Vol 1, Pt 5, Ch 3. This is to include the effects of any pod to pod and/or pod to ship hydrodynamic interference effects. The designer is to supply the following maximum load and moment values to which the unit may be subjected with a description of the operating condition at which they occur.

- F_x, Force in the longitudinal direction;

- F_y, Force in the transverse direction;
- F_z, Force in the vertical direction including self weight, in water, augmented by the ship's pitch and heave motion and flodded volume where applicable, *see Vol 2, Pt 4, Ch 4, 5.3 Direct calculations 5.3.3* and *Vol 1, Pt 5, Ch 3 Local Design Loads*;
- M_x, moment at the slewing ring about the pod unit's global longitudinal axis;
- M_y, moment at the slewing ring about the pod unit's global transverse axis;
- M_z, moment at the slewing ring about the pod unit's vertical axis (maximum dynamic duty steering torque on steerable pods).

The directions of the X, Y and Z axes, with the origin at the centre of the slewing ring, are shown in *Figure 4.2.1 Pod co-ordinate system*.

2.4.2 Where the maximum forces and moments defined in *Vol 2, Pt 4, Ch 4, 2.4 Global loads 2.4.1* cannot be accurately calculated, then an estimate of these loadings is to be stated together with an assessment of the associated error tolerances for the sequences of permitted design manoeuvres, *see Vol 2, Pt 4, Ch 4, 1.1 Application 1.1.7*. Typically this will include emergency astern manoeuvres, zig zag manoeuvres and pod interaction. Such estimates are to be defined on a load versus pod angle basis. In the case of pod to pod and/or pod to ship hydrodynamic interaction effects, these must be defined for the most severely affected propulsor including cases where pod units are capable of being independently steered.

2.4.3 Where control systems are installed to limit the operation of the podded drive to defined angles at defined ship speeds, this information may be taken into consideration when determining the pod unit loading.

2.4.4 Where pod units are fixed about their Z axis, then maximum global loads, to be used as the basis of the structural appraisal, are to be determined for inflows in 5 degree increments between the extremes of anticipated inflow angle during manoeuvring with ship at full speed and maximum propeller thrust.

2.4.5 The podded propulsor is to be capable of withstanding a blade root failure due to fatigue occurring at the maximum rated output of the podded propulsor without initiating a failure in other parts of the propulsor system. After a blade failure, the podded propulsor is to be capable of reduced power operation in accordance with the manufacturer's instructions.

2.5 Ice Class Requirements

2.5.1 Where an ice class notation is included in the class of a ship, additional requirements as detailed in *Vol 3, Pt 1, Ch 1 Ice Navigation - First-Year Ice Conditions* are to be complied with as applicable.

■ *Section 3* Functional capability

3.1 General

3.1.1 The arrangement of podded propulsion units is to be such that the ship can be satisfactorily manoeuvred to a declared performance capability. The operating conditions covered are to include the following:

(a) Maximum continuous shaft power/speed to the propeller in the ahead condition at the declared steering angles and sea conditions.
(b) Manoeuvring speeds of the propeller shaft in the ahead and astern direction at the declared steering angles and sea conditions.
(c) The stopping manoeuvre described in *Vol 2, Pt 1, Ch 2 Requirements for Machinery and Engineering Systems of Unconventional Design*.
(d) All astern running conditions for the ship.
(e) Manoeuvring in ice where ice class is required.

3.1.2 The main steering arrangements are to be operated by power and capable of changing the direction of the ship's podded propulsion units from one side to the other at declared steering angle limits at an average rotational speed of not less than 0,4 rev/min with the ship initally operating at its maximum ahead service speed.

3.1.3 The auxiliary steering arrangements are to be:

(a) Capable of changing the direction of the ship's podded propulsion units from one side to the other at declared steering angle limits at an average rotational speed of not less than 0,083 rev/min, with the ship running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater.
(b) Operated by power for ships having propulsion power of more than 2500 kW per podded propulsion unit and for all ships, where it is necessary, to meet the requirements of *Vol 2, Pt 4, Ch 4, 3.1 General 3.1.3*.

■ *Section 4* **Materials**

4.1 General

4.1.1 The materials used for major structural and machinery components are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials). These components include hull support structure, pod body, pod strut, shafting and propellers.

4.1.2 Components of novel design or components manufactured from materials not covered by the Rules for Materials are to be subject to evaluation and approval by LR prior to manufacture.

4.1.3 Material specifications, *see Vol 2, Pt 4, Ch 4, 2.2 Documentation required for design review 2.2.1*, for propulsion shaft and slewing ring bearings, gearing and couplings are to be approved by LR prior to manufacture. The specification is to include details of the grade of material, including the target range of chemical composition that is to be reported on the certificate, the required mechanical properties, heat treatment details including temperatures and hold times, details of necessary non-destructive examinations including acceptance levels. Additionally, any steel cleanness or microstructure requirements are to be included. These components are to be manufactured under survey.

4.1.4 For propulsion shaft rolling element bearings the amount of retained austenite is to be determined and is not to exceed 4 per cent for nominally bainitic structures.

4.1.5 Where load carrying threaded fasteners screw directly into structural castings, the integrity of the casting is to be such that there is no porosity or shrinkage in the area of the connection.

■ *Section 5* **Structure design and construction requirements**

5.1 Pod structure

5.1.1 Podded unit struts and pod bodies may be of cast, forged or fabricated construction or a combination of these construction methods.

5.1.2 Means are to be provided to enable the propeller shaft, bearings and seal arrangements to be examined in accordance with LR's requirements and the manufacturer's recommendations.

5.1.3 When high tensile steel fasteners are used as part of the structural arrangement and there is a risk that these fasteners may come into contact with sea-water, carbon-manganese and low alloy steels with a specified tensile strength of greater than 950 N/mm^2 are not to be used due to the risk of hydrogen embrittlement.

5.1.4 For steerable pod units, an integral slewing ring is to be arranged at the upper extremity of the strut to provide support for the slewing bearing.

5.1.5 The strut is to have a smooth transition from the upper mounting to the lower hydrodynamic sections.

5.1.6 For fabricated structures, vertical and horizontal plate diaphragms are to be arranged within the strut and, where necessary, secondary stiffening members are to be arranged.

5.1.7 Pod unit structure scantling requirements are shown in *Table 4.5.1 Podded propulsion unit - fabricated structure requirements*. Where the scantling requirements in *Table 4.5.1 Podded propulsion unit - fabricated structure requirements* cannot be satisfied, direct calculations carried out in accordance with *Vol 2, Pt 4, Ch 4, 5.3 Direct calculations* may be considered.

Table 4.5.1 Podded propulsion unit - fabricated structure requirements

Location	Requirement	Notes
Strut external shell plating	Thickness, in mm, is to be not less than: $t = 0{,}0063 s\, f\, (h_7\, k)^{0,5}$	The minimum thickness of plating diaphragms and primary webs within the strut is to be not less than the Rule requirement for the strut external plating. For internal diaphragms, panel stiffening is to be provided where the ratio of spacing to plate thickness (*s*/*t*) exceeds 100. Where there are no secondary members, *s* is to be replaced by *S*.
Strut primary framing	The section modulus in cm^3 is to be not less than: $z = 7{,}75 h_7\, l_e^{\,2}\, S\, k$	This does not apply to full breadth plate diaphragms.
Strut secondary stiffening	The section in cm^3 is to be not less than: $z = 0{,}0056 h_7\, l_e^{\,2}\, s\, k$	This does not apply to full breadth plate diaphragms.
Cylindrical pod body external shell plating	Thickness, in mm, is to be not less than: $t = 3{,}0 R$g $(h_7\, k)^{0,5}$	
Symbols		
f = panel aspect ratio correction factor = [1,1 – s/(2500S)] h_7 = $(T + C_w + 0.014V^2)$ k = local higher tensile steel factor, as in *Vol 1, Pt 6, Ch 2 Design Tools* l_e = effective span of the member under consideration, in metres s = the frame spacing of secondary members, in mm C_w = design wave amplitude, in metres, as in *Table 3.2.1 Ship motions* in Vol 1, Pt 5, Ch 3 R_g = mean radius of pod body tube, in metres S = the spacing of primary members, in metres T = the vessel scantling draft, in metres, as in *Vol 1, Pt 3, Ch 1, 5.2 Principal particulars* V = maximum design speed, in knots, as in *Vol 1, Pt 3, Ch 3, 2.11 Rudder force, FR*		

5.1.8 The connection between the strut and the pod body should generally be effected through large radiused fillets in cast pod units or curved plates in fabricated pod units.

5.1.9 The structural response under the most onerous combination of loads is not to exceed the normal operational requirements of the propulsion or steering system components.

5.1.10 For cast pod structures, the elongation of the material on a gauge length of $5.65\sqrt{S_o}$ is to be not less than 12 per cent where S_o is the actual cross sectional area of the test piece.

5.1.11 In castings, sudden changes of section or possible constriction to the flow of metal during casting are to be avoided. All fillets are to have adequate radii which should, in general, be not less than 75 mm.

5.1.12 Castings are to comply with the requirements of *Ch 4 Steel Castings* or *Ch 7 Iron Castings* of the Rules for Materials.

5.2 Hull support structure

5.2.1 For supporting the main slewing bearing outer faces, a system of primary structural members is to be provided in order to transfer the maximum design loads and moments from the podded propulsion unit into the ship's hull without undue deflection. Due account is also to be taken of the loads induced by the maximum ship's motions in the vertical direction resulting from combined heave and pitch motion of the ship. Account is also to be taken of any manoeuvring conditions that are likely to give rise to high mean or vibratory loadings induced by the podded propulsion unit. *See Vol 2, Pt 4, Ch 4, 2.2 Documentation required for design review 2.2.1*.

5.2.2 The hull support structure in way of the slewing bearing should be sufficiently stiff that the bearing manufacturer's limits on seating flatness are not exceeded due to hull flexure as a consequence of the loads defined under *Vol 2, Pt 4, Ch 4, 5.2 Hull support structure 5.2.1*.

5.2.3 Generally, the system of primary members is to comprise a pedestal girder directly supporting the slewing ring and bearing. The pedestal girder is to be integrated with the ship's structure by means of radial girders and transverses aligned at their outer ends with the ship's bottom girders and transverses, *see Figure 4.5.1 Hull support structure*. Proposals to use alternative arrangements that provide an equivalent degree of strength and rigidity may be submitted for appraisal.

5.2.4 The ship's support structure in way of the podded unit may be of double or single bottom construction. Generally, podded drives should be supported where practical within a double bottom structure; however final acceptance of the supporting arrangements will be dependent upon satisfying the stress criteria set out in *Table 4.5.2 Direct calculation maximum permissible stresses for steel fabricated structures*, *see also Vol 2, Pt 4, Ch 4, 5.3 Direct calculations 5.3.5*.

5.2.5 The shell envelope plating and tank top plating in way of the aperture for the podded drive (i.e. over the extent of the radial girders shown in *Figure 4.5.1 Hull support structure*) is to be increased by 50 per cent over the Rule minimum thickness to provide additional local stiffness and robustness. However, the thickness of this plating is not to be less than the actual fitted thickness of the surrounding shell or tank top plating.

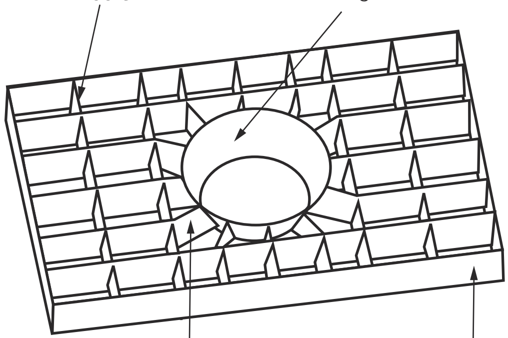


Figure 4.5.1 Hull support structure

5.2.6 The scantlings of the primary support structure in way of the podded drive are to be based upon the limiting design stress criteria specified in *Table 4.5.2 Direct calculation maximum permissible stresses for steel fabricated structures*, *see also Vol 2, Pt 4, Ch 4, 5.3 Direct calculations 5.3.5*. Primary member scantlings are, however, not to be less than those required by *Vol 1, Pt 6, Ch 3, 7 Single bottom structures* and *Vol 1, Pt 6, Ch 3, 8 Double bottom structures*.

Table 4.5.2 Direct calculation maximum permissible stresses for steel fabricated structures

Permissible stress values		
Location	Podded drive structure	Podded drive/hull interface
X-Y shear stress	0,26σ_o	0,35σ_o
Direct stress due to bending	0,33σ_o	0,63σ_o

Von Mises stress	0,40σ_o	0,75σ_o
Localised Von Mises peak stresses	σ_o	σ_o
Symbols		
σ_o = minimum yield strength of the material		
Note 1. The values stated above are intended to give an indication of the levels of stress in the pod and ship structure for the maximum loads which could be experienced during normal service. **Note** 2. If design is based on extreme or statistically low probability loads, then proposals to use alternative acceptance stress criteria may be considered.		

5.2.7 The pedestal girder is to have a thickness not less than the required shell envelope minimum Rule thickness in way. Where abutting plates are of dissimilar thickness, then the taper requirements of *Vol 1, Pt 6, Ch 4 Hull Girder Strength* are to be complied with.

5.2.8 In general, full penetration welds are to be applied at the pedestal girder boundaries and in way of the end connections between the radial girders and the pedestal girder. Elsewhere, for primary members, double continuous fillet welding is to be applied using a minimum weld factor of 0,34.

5.3 Direct calculations

5.3.1 Finite element or other direct calculation techniques may be employed in the verification of the structural design. The mesh density used is to be sufficient accurately to demonstrate the response characteristics of the structure and to provide adequate stress and deflection information. A refined mesh density is to be applied to geometry transition areas and those locations where high localised stress or stress gradients are anticipated.

5.3.2 Model boundary constraints are generally to be applied in way of the slewing ring/ship attachment only.

5.3.3 The loads applied to the mathematical model, *see Vol 2, Pt 4, Ch 4, 2.4 Global loads 2.4.1*, are to include the self weight, dynamic acceleration due to ship motion, hydrodynamic loads, hydrostatic pressure, propeller forces and shaft bearing support forces. In situations where a pod can operate in the flodded conditions or where flooding of a pod adds significant mass to the pod, details are to be included.

5.3.4 Based on the most onerous combination of normal service loading conditions, the stress criteria shown in *Table 4.5.2 Direct calculation maximum permissible stresses for steel fabricated structures* are not to be exceeded. *See also Vol 2, Pt 4, Ch 4, 2.2 Documentation required for design review 2.2.1*.

5.3.5 Where the structural design is based on a fatigue assessment and the stress criteria shown in *Table 4.5.2 Direct calculation maximum permissible stresses for steel fabricated structures* are not applicable, details of cumulative load history and stress range together with the proposed acceptance criteria are to be submitted for consideration.

5.3.6 For cast structures, the localised von Mises stress should not exceed 0,6 times the nominal 0,2 per cent proof or yield stress of the material for the most onerous design condition.

■ *Section 6*
Machinery design and construction requirements

6.1 General

6.1.1 The requirements detailed in *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems* are applicable.

6.1.2 Means are to be provided whereby normal operation of the podded propulsion system can be sustained or readily restored if one of the supporting auxiliaries becomes inoperative. *See also Vol 2, Pt 4, Ch 4, 2.1 Pod arrangement 2.1.1*. Consideration shall be given to the malfunctioning of:

- sources of lubricating oil pressure,

- sources of cooling,
- hydraulic, pneumatic or electrical means for control of the podded propulsor.

6.2 Gearing

6.2.1 If gearing is used in the propulsion system then the requirements of *Vol 2, Pt 3, Ch 1 Gearing* are applicable.

6.3 Propulsion shafting

6.3.1 In addition to meeting the requirements of *Vol 2, Pt 3, Ch 2 Shafting Systems* and *Vol 2, Pt 5 Shaft Vibration and Alignment*, the pod propulsion shafting supporting an electric motor is to be sufficiently stiff that both static and dynamic shaft flexure are within the motor manufacturer's limits for all envisaged operating conditions.

6.3.2 There is to be no significant lateral vibration response that may cause damage to the shaft seals within ±20 per cent of the running speed range. For vibration analysis computations the influence of the slewing ring and shaft bearing stiffnesses together with the contribution from the seating stiffnesses are to be included in the calculation procedures.

6.3.3 As an alternative to the requirements of*Vol 2, Pt 3, Ch 2 Shafting Systems*, a fatigue strength analysis of shafting components indicating a factor of safety of 1,5 at the design loads based on a suitable fatigue failure criterion may be submitted for consideration. The effects of stress concentrations, material properties and operating environment are to be taken into account.

6.3.4 With the exception of the propeller connection (requirements stated in *Vol 2, Pt 4, Ch 1 Propellers*) couplings relying on friction are to have a factor of safety of 2,5 against slippage at the maximum rated torque. In order to reduce the possibility of fretting, a grip stress of not less than 20 N/mm^2 is to be attained.

6.3.5 The effects of motor short-circuit torque on the shafting system should not prevent continued operation once the fault has been rectified.

6.3.6 The arrangement of shaft bearings is to take account of shaft thermal expansion, misalignment of bearings, shaft slope through the bearings and manufacturing tolerances. Additionally, the influence of the pod deflection on the shaft bearing alignment is to be considered under the most onerous mechanical and hydrodynamic loading conditions.

6.3.7 Propeller shaft roller bearing life calculations are to take account of the following loadings:

- Shaft, motor, propeller and other shaft appendages' weights;
- Forces due to ship's motion;
- The propeller-generated forces and moments about the three Cartesian axes related to the shaft; f_x, f_y, f_z, m_x, m_y, m_z, *see Figure 4.2.1 Pod co-ordinate system*;
- Side loads on propeller;
- Variance of propeller-generated forces and moments with pod azimuth angle. This load variance should take account of the motor control characteristics;
- Forces due to pod rotation, including gyroscopic forces;
- A predicted azimuth service profile for the pod indicating the proportion of time spent at various azimuth angles;
- Loads due to hydrodynamic interaction between pods;
- Any additional loads experienced during operation in ice conditions (for Ice Class notations);
- Where validation of the above loadings is available, detailed calculations must demonstrate that the bearing life when operating at the normal duty profile will comfortably exceed the time between 6-yearly surveys. Parameters used to justify the bearing life, i.e. those related to oil cleanliness, viscosity limits and material quality are to be quoted.

6.3.8 Where detailed validation of the loadings identified in *Vol 2, Pt 4, Ch 4, 6.3 Propulsion shafting 6.3.7* is not available, the calculations for roller bearings are to indicate a bearing life greater than 65 000 hours at the maximum continuous rating of the podded drive taking into account the azimuth angle duty cycle. Any parameters used to justify this life, i.e. those related to oil cleanliness, water contamination and viscosity limits are to be quoted. Proposals for the use of a shaft bearing of life less than 65 000 hours will be considered on application with details of alleviating factors and supporting documentation, however this bearing life must exceed the time between surveys.

6.3.9 The design of the shaft line bearings is to take account of the maximum and minimum operating temperatures likely to be encountered during both a voyage cycle and, more widely, during the ship's operational life. Furthermore, any anticipated temperature distributions through the bearing components and structures are to be included in the design calculations.

6.3.10 Means are to be provided for detecting shaft bearing deterioration. Where rolling element shaft bearings are used in single pod applications or in pods where the motor power exceeds 6 MW, vibration monitoring of the shaft bearings is to be

provided. The bearing monitoring system is to be suitable for the local bearing conditions and is to be able to differentiate from other vibration sources such as propeller cavitation or ship motions.

6.3.11 In multi-podded propulsor systems or ships having at least one pod in association with other propulsion devices and where the individual pod installed power is greater than 5MW, means are to be provided to hold the propeller for an inoperable unit stationary whilst the other pod(s) propel the vessel at a manoeuvring speed of not less than 7 knots. Operating instructions displayed at the holding mechanism's operating position are to include a direction to inform the bridge of any limitation in ships speed required as a result of the holding mechanism being activated.

6.3.12 Shaft seals for maintaining the watertight integrity of the pod are to be Type Approved to a standard acceptable to LR. The seals are to be designed to withstand the extremes of operation for which they are intended and this is to include extremes of temperature, vibration, pressure and shaft movement.

6.3.13 In single pod installations, the integrity of shaft seals is to be evaluated on the basis of a double failure. In such installations, seal duplication is to be used with indication of failure of one seal being provided.

6.4 Propeller

6.4.1 The requirements of *Vol 2, Pt 4, Ch 1 Propellers* are to be complied with.

6.4.2 Where propeller scantlings have been determined by a detailed fatigue analysis, based on reliable wake survey data as described in *Vol 2, Pt 4, Ch 1, 7.1 Minimum blade thickness 7.1.8*, a factor of safety of 1,5 against suitable fatigue failure criteria is to be demonstrated. The effects of fillet stress concentrations, residual stress, fluctuating loads and material properties are to be taken into account.

6.5 Bearing lubrication system

6.5.1 The bearing lubrication system is to be arranged to provide a sufficient quantity of lubricant of a quality, viscosity and temperature acceptable to the bearing manufacturer under all ship operating conditions.

6.5.2 In addition to the requirements detailed in this Section, the requirements of *Vol 2, Pt 7, Ch 3, 8 Lubricating oil systems* as applicable are to be complied with.

6.5.3 For systems employing forced lubrication, the sampling points required by *Vol 2, Pt 7, Ch 3, 8.13 Lubricating oil contamination 8.13.6* are to be located such that the sample taken is representative of the oil present at the bearing.

6.5.4 For lubricating oil systems employing gravity feed, the arrangements are to be such as to permit oil sampling and oil changes in accordance with the manufacturer's instructions for the safe and reliable operation of the propulsion system.

6.5.5 Where continuous operation of the lubricating oil system is essential for the pod to operate at its maximum continuous rating, a standby pump in accordance with *Vol 2, Pt 7, Ch 3, 8.2 Pumps 8.2.2* is to be provided. In such systems, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the pod.

6.5.6 Where bearings are grease lubricated, means are to be provided for collecting waste grease to enable analysis for particulates and water. The arrangements for collecting waste grease are to be in accordance with the pod manufacturer's recommendations. Alternative arrangements which demonstrate that bearings are satisfactorily lubricated will be considered.

6.5.7 Pipework conveying lubricating oil is to be sited such that any possible leakage from joints will not impinge on electrical equipment, hot surfaces or other sources of ignition, *see also Vol 2, Pt 7, Ch 2, 2.8 Miscellaneous requirements 2.8.2*.

6.5.8 The procedures for flushing the lubrication system are to be defined. This procedure is to embrace the following conditions:

(a) Initial installation.
(b) Post maintenance situations.
(c) Major dry-docking refits.

See Vol 2, Pt 4, Ch 4, 10 Installation, maintenance and replacement procedures.

6.6 Steering system

6.6.1 The requirements of Pt 6, Ch 1, Sections *Vol 2, Pt 6, Ch 1, 1 General requirements*, *Vol 2, Pt 6, Ch 1, 2 Documentation required for design review*, *Vol 2, Pt 6, Ch 1, 3 Materials*, *Vol 2, Pt 6, Ch 1, 4 Performance*, *Vol 2, Pt 6, Ch 1, 5 Design and construction*, *Vol 2, Pt 6, Ch 1, 8 Monitoring and alarms* and *Vol 2, Pt 6, Ch 1, 9 Alternative sources of power and emergency operation* are to be complied with where applicable. *See also Vol 2, Pt 4, Ch 4, 3.1 General*.The requirements of *Vol 2, Pt 6, Ch 1, 4.1 General 4.1.2* and *Vol 2, Pt 6, Ch 1, 4.1 General 4.1.2* are addressed by *Vol 2, Pt 4, Ch 4, 3.1 General 3.1.2* and the

requirements of *Vol 2, Pt 6, Ch 1, 4.1 General 4.1.3* and *Vol 2, Pt 6, Ch 1, 4.1 General 4.1.3* are addressed by *Vol 2, Pt 4, Ch 4, 3.1 General 3.1.3*.

6.6.2 For vessels where a single podded propulsion unit is the sole means of propulsion, the requirement for auxiliary steering arrangements in *Vol 2, Pt 6, Ch 1, 4 Performance* is to be achieved by means of two or more identical power units.

6.6.3 For vessels with more than one steerable podded propulsion unit, the requirement for auxiliary steering arrangements in *Vol 2, Pt 6, Ch 1, 4 Performance* is to be achieved by equipping each of the podded propulsion units with its own dedicated and independent steering gear control system and power actuating system. Consideration will be given to alternative arrangements, providing equivalence can be demonstrated.

6.6.4 Steering arrangements, other than of the hydraulic type, may be accepted provided that there are means of limiting the maximum torque to which the steering arrangement may be subjected.

6.6.5 The steering mechanism is to be provided with power that is sufficient for the maximum steering torques present during the declared functional capability identified in *Vol 2, Pt 4, Ch 4, 3.1 General* and is to be demonstrated for the most onerous specified manoeuvring trial, *see Vol 2, Pt 4, Ch 4, 9 Testing and trials*.

6.6.6 Geared arrangements employed for steering are to consider the following conditions:

- A design maximum dynamic duty steering torque, M_z, *see Vol 2, Pt 4, Ch 4, 2.4 Global loads 2.4.1*;
- A static duty ($\leq 10^3$ load cycles) steering torque. The static duty steering torque should not be less than M_W, the maximum torque which can be generated by the steering gear mechanism.

The minimum factors of safety, as derived using ISO 6336 Calculation of load capacity of spur and helical gears, or a recognised National Standard, are to be 1.5 on bending stress and 1,0 on Hertzian contact stress. The use of a duty factor in the dynamic duty strength calculations is acceptable but the derivation of such a factor, based on percentage of time spent at a percentage of the maximum working torque, should be submitted to LR for consideration and acceptance.

6.6.7 Slewing ring bearing capacity calculations are to take account of:

- Pod weight in water;
- Gyroscopic forces from the propeller and motor;
- Hydrodynamic loads on pod; and
- Forces due to ship's motions.

The calculations are to demonstrate that the factor of safety against the maximum combination of the above forces is not less than 2. The calculations are to be carried out in accordance with a suitable declared standard.

6.6.8 Means of allowing the condition of the slewing gears and bearings to be assessed are to be provided.

6.6.9 On multi podded ships, means are to be provided to secure each pod unit’s slewing mechanism in its ahead or zero degree position in the event of a steering system failure. These arrangements are to be of sufficient strength to hold the pod in position at the ship's manoeuvring speed to be taken as not less than 7 knots, *see also Vol 2, Pt 4, Ch 4, 6.3 Propulsion shafting 6.3.9*. Operating instructions displayed at the securing mechanism’s operating position are to include a direction to inform the bridge of any limitation in ships speed required as a result of the securing mechanism being activated.

6.7 Ventilation and Cooling Systems

6.7.1 Means are to be provided to ensure that air used for motor cooling purposes is of a suitable temperature and humidity as well as being free from harmful particles.

6.7.2 Cooling water supplies are to comply with *Vol 2, Pt 7, Ch 3, 12 Air compressors and air starting arrangements*. *see also Vol 2, Pt 9, Ch 3, 6.5 Machine enclosure 6.5.1*.

6.7.3 On single podded installations, a standby cooling arrangement of the same capacity as the main cooling system, is to be provided and available for immediate use.

6.7.4 For pods having an electric propulsion motor but no active cooling system, heat balance calculations as required by *Vol 2, Pt 4, Ch 4, 2.2 Documentation required for design review 2.2.1* are to demonstrate that the pod unit and associated systems are able to function satisfactorily over all operating conditions, *see Vol 2, Pt 1, Ch 3, 4.4 Ambient reference conditions*.

6.8 Pod drainage requirements

6.8.1 Unless the electrical installation is suitable for operation in a flooded space, means are to be provided to ensure that leakage from shaft bearings or the propeller seal do not reach the motor windings, or other electrical components. Account is to be taken of cooling air flow circulating within the pod unit.

6.8.2 Where the design of a pod space has a requirement to be maintained in a dry condition, two independent means of drainage are to be provided so that liquid leakage may be removed from the pod unit at all design angles of heel and trim, *see Vol 2, Pt 1, Ch 3, 4.6 Inclination of ship*.

6.8.3 Pipework conveying leakage from the pod is to be sited such that any leakage from joints will not impinge on electrical equipment, *see also Vol 2, Pt 7, Ch 2, 2.8 Miscellaneous requirements 2.8.2*.

6.9 Hydraulic actuating systems

6.9.1 Hydraulic actuating systems are to comply with *Vol 2, Pt 6, Ch 1, 5 Design and construction* and *Vol 2, Pt 7, Ch 5, 11 Hydraulic power actuating systems* as applicable.

■ *Section 7* Electrical equipment

7.1 General

7.1.1 The electrical installation is to be designed, constructed and installed in accordance with the requirements of *Vol 2, Pt 9 Electrotechnical Systems*.

7.1.2 Means are to be provided to prevent electrical currents flowing across shaft bearings, which may cause their premature failure.

7.1.3 Steering gear electrical systems are to comply with *Vol 2, Pt 6, Ch 1, 7 Electrical power circuits and equipment*.

7.1.4 Details are to be submitted to demonstrate the suitability of cables and busbars intended to operate at temperatures exceeding 95°C, *see Vol 2, Pt 9, Ch 3, 5.2 Busbars 5.2.2* and *Vol 2, Pt 9, Ch 3, 8.4 Operating temperature 8.4.3*.

7.2 Slip rings

7.2.1 Where slip rings are incorporated in the design, the details of the following are to be submitted for consideration:

(a) temperature rise test reports;
(b) maximum permitted temperature ratings and design operating temperatures for materials;
(c) where applicable, arrangements for forced air or liquid cooling;
(d) for data communication link slip rings, evidence to demonstrate compliance with *Vol 2, Pt 9, Ch 8, 5.2 Data communication links 5.2.3*;
(e) suitability for use under the conditions of vibration expected to arise in normal operation;
(f) evidence of satisfactory operation under the normal angles of inclination given in *Vol 2, Pt 9, Ch 1, 2.3 Ambient reference and operating conditions*;
(g) cable securing arrangements; and
(h) evidence of electromagnetic compatibility of control, alarm and safety systems with power circuits.

7.2.2 Where forced cooling is used on slip rings, an alarm is to be initiated to indicate the failure of the forced cooling and it is to be possible to operate the slip ring at a reduced power level defined by the manufacturer in the event of failure of the forced cooling.

■ Section 8
Control engineering arrangements

8.1 General

8.1.1 Control engineering arrangements are to be in accordance with *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*.

8.1.2 Steering gear control, monitoring and alarm systems are to comply with *Vol 2, Pt 6, Ch 1, 6 Steering control systems*and *Vol 2, Pt 6, Ch 1, 7 Electrical power circuits and equipment*.

8.1.3 Steering control is to be provided for podded drives from the navigating bridge and locally.

8.1.4 An indication of the angular position of the podded propulsion unit(s) and the magnitude of the thrust is to be provided at each station from which it is possible to control the direction of thrust. This indication is to be independent of the steering control system.

8.1.5 Emergency Stop Functions are to be provided at the remote control station(s), independent of the podded drive control system, to stop each podded drive in an emergency. *see also Vol 2, Pt 4, Ch 5, 4.4 Propulsion control 4.4.7*.

8.1.6 Where programmable electronic equipment is used to prevent loads exceeding those for which the system has been designed (*see Vol 2, Pt 4, Ch 4, 2.4 Global loads 2.4.3*), then either:

(a) A fully independent hard wired back up is to be provided; or
(b) The software is to be certified in accordance with LR's Software Conformity Assessment System – Assessment Module GEN1 (1994) and have an independent solution showing redundancy with design diversity, etc. *see Vol 2, Pt 9, Ch 8, 5.4 Additional requirements for Mobility category and safety critical systems*.

8.1.7 Where a propulsion system which includes a podded propulsor unit is controlled by a series of interactive and integrated programmable electronic systems, then these are to comply with the requirements of *Vol 2, Pt 9, Ch 8, 5.5 Additional requirements for integrated systems*.

8.1.8 For electronic control systems and electrical actuating systems, an overall quality plan for sourcing, design, installation and testing is to address the following issues:

(a) Standard(s) applied.
(b) Details of the quality control system applied during manufacture and testing.
(c) Details of type approval, type testing or approved type status assigned to the equipment.
(d) Details of installation and testing recommendations for the equipment.
(e) Details of any local and/or remote diagnostic arrangements where assessment and alteration of control parameters can be made which can affect the operation of the podded propulsor unit.
(f) Software lifecycle activities, including configuration management and arrangements for software upgrades.

8.1.9 The quality plan referred to in *Vol 2, Pt 4, Ch 4, 8.1 General 8.1.8* is to identify the process for verification of the functional outputs from the electronic control systems with particular reference to system integrity, consistency, security against unauthorised changes to software and maintaining the outputs within acceptable tolerances of stated performance for safe and reliable operation of the podded propulsor unit.

8.1.10 For the permitted range of operating conditions, the control system is to be capable of protecting the podded propulsor from experiencing mechanical loads that may initiate damage while permitting the desired manoeuvres to take place.

8.2 Monitoring and alarms

8.2.1 The requirements for alarms and monitoring arrangements are to be in accordance with *Vol 2, Pt 6, Ch 1, 8.1 Monitoring* and *Table 4.8.1 Additional alarms and safeguards for podded propulsion units*. These alarms are in addition to the requirements of *Vol 2, Pt 4, Ch 5, 4 Electric propulsion systems*.

Table 4.8.1 Additional alarms and safeguards for podded propulsion units

Item	Alarm	Note
Podded drive azimuth angle	—	Indicator, *see Vol 2, Pt 4, Ch 4, 8.1 General 8.1.4*

Propulsion motors	Power supply failure	To be indicated on the navigating bridge
Propulsion motor power limitation or automatic reduction	Activated	*See also Vol 2, Pt 4, Ch 5, 4.4 Propulsion control 4.4.9*
Hydraulic oil system pressure	Low	To be indicated on the navigating bridge
Bearing temperature	High	For grease lubricated bearings
Motor temperature	High	*See Vol 2, Pt 4, Ch 5, 4.1 General 4.1.5*
Lubricating oil supply pressure	Low	If separate forced lubrication for shaft bearings; to be indicated on the navigating bridge
Lubricating oil temperature	High	*See also Vol 2, Pt 4, Ch 5, 4.5 Protection of propulsion system 4.5.9*
Lubricating oil tank level for motor bearings	Low	
Water in lubricating oil for motor bearings	High	Required for single podded propulsion units only
Motor cooling air inlet temperature	High	
Motor cooling air outlet temperature	High	
Motor cooling air flow	Low	
Shaft bearing vibration monitoring	High	*See Vol 2, Pt 4, Ch 4, 6.3 Propulsion shafting 6.3.10*. Monitoring is to allow bearing condition to be gauged using trend analysis.
Shaft sealing	Water ingress	*See Vol 2, Pt 4, Ch 4, 6.3 Propulsion shafting 6.3.13*
Dry space water pump operation	Abnormal	Alarm set to indicate a frequency or duration exceeding that which would normally be expected.
Dry space water level	1st stage high 2nd stage high	— Propulsion motor is to shut down automatically, *See* Note
Slip ring forced cooling	Failure	*See Vol 2, Pt 4, Ch 4, 7.2 Slip rings 7.2.2*

Note The second stage dry space water level high alarm is not needed where the electrical equipment installed within the pod is suitable for operation in flooded spaces, *see Vol 2, Pt 4, Ch 4, 6.8 Pod drainage requirements 6.8.1*.

8.2.2 Alarms specified in *Table 4.8.1 Additional alarms and safeguards for podded propulsion units* are to be in accordance with the alarm system specified by *Vol 2, Pt 9, Ch 7, 4.3 Alarm systems, general requirements*.

8.2.3 Sensors for control, monitoring and alarm systems required by the Rules and located within the pod are to be duplicated in order that a single sensor failure does not inhibit system functionality.

8.2.4 Pod unit dry space pumping arrangements are to function automatically in the event of a high liquid level being detected in the pod unit.

8.2.5 Spaces intended to be dry are to be provided with arrangements to indicate water ingress in accordance with *Vol 2, Pt 4, Ch 4, 8.2 Monitoring and alarms 8.2.6* and *Table 4.8.1 Additional alarms and safeguards for podded propulsion units*.

8.2.6 The number and location of dry space level detectors are to be such that accumulation of liquids will be detected at all design angles of heel and trim.

8.2.7 Condition monitoring arrangements are not to interface with the operation of safety systems which may cause slow-down or shutdown of the propulsion system. *See also Vol 2, Pt 9, Ch 7, 4.6 Bridge control for main propulsion machinery 4.6.8*.

8.2.8 Means are to be provided to identify the cause of propulsion motor power limitation or automatic reduction.

Section 9
Testing and trials

9.1 General

9.1.1 The following requirements are to be complied with:

- *Vol 2, Pt 1, Ch 3, 16 Sea trials* for sea trials.
- *Vol 2, Pt 1, Ch 3, 15 Steering systems* for steering trials.

In addition, the functional capability specified in *Vol 2, Pt 4, Ch 4, 3.1 General 3.1.1* is to be demonstrated to the Surveyor's satisfaction.

9.1.2 The actual values of steering torque are to be verified during sea trials to confirm that the design maximum dynamic duty torque has not been exceeded.

9.1.3 Electric motor cooling systems are to be verified, as far as possible, to ensure that they are capable of limiting the extremes of ambient temperature to those specified in *Vol 2, Pt 4, Ch 4, 2.3 Pod internal atmospheric conditions 2.3.1*.

9.1.4 Any trials and testing identified from the Risk Assessment report, *see Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*, are also to be carried out.

Section 10
Installation, maintenance and replacement procedures

10.1 General

10.1.1 All podded propulsion units are to be supplied with a copy of the manufacturer's installation and maintenance manual that is pertinent to the actual equipment.

10.1.2 The manual required by *Vol 2, Pt 4, Ch 4, 10.1 General 10.1.1* is to be placed on board and is to contain the following information:

(a) Description of the podded propulsion unit with details of function and design operating limits. This is also to include details of support systems such as lubrication, cooling and condition monitoring arrangements.
(b) Identification of all components together with details of any that have a defined maximum operating life.
(c) Instructions for installation of unit(s) on board ship with details of any required specialised equipment.
(d) Instructions for commissioning at initial installation and following maintenance.
(e) Maintenance and service instructions to include inspection/renewal of bearings, seals, motors, slip rings and other major components. This is also to include component fitting procedures, special environmental arrangements, clearance and push-up measurements and lubricating oil treatment where applicable.
(f) Actions required in the event of fault/failure conditions being detected.
(g) Precautions to be taken by personnel working during installation and maintenance.

■ *Scope*

The requirements of this Chapter are applicable to the design and construction philosophy of electrical propulsion systems that utilise converter fed propulsion motors.

This Chapter details the requirements for electric propulsion system as a standalone system as well as integrated electrical power generation and propulsion systems.

■ *Section 1* Functional requirements

1.1 Functional requirements

1.1.1 Electric propulsion machinery shall enable the ship to manoeuvre as and when required, and remain within the designed or imposed limitations in both ahead and astern modes of operation.

■ *Section 2* Performance requirements

2.1 Performance requirements

2.1.1 The propulsion equipment and systems shall be designed, constructed and maintained to minimise danger to personnel on board in all foreseeable operating conditions.

2.1.2 The design, construction, installation and operation of propulsion equipment shall not cause interference or excessive forces that could lead to its failure or failure of other equipment and systems.

2.1.3 Effective means of communicating orders from the conning positions to any position from which the speed and direction of thrust of the propellers can be controlled shall be provided.

2.1.4 Means shall be provided whereby normal operation of propulsion machinery can be sustained or restored even though one of the essential auxiliaries becomes inoperative.

Section 3
Verification requirements

3.1 General

3.1.1 Compliance with the requirements in *Vol 2, Pt 4, Ch 5, 4 Electric propulsion systems* is deemed to satisfy the functional requirements and performance requirements above.

3.1.2 Where a designer offers a novel solution, an engineering safety and justification report is to be submitted. The engineering safety and justification report is to demonstrate how the proposed solution will satisfy the functional requirements and performance requirements in *Vol 2, Pt 4, Ch 5, 1 Functional requirements* and *Vol 2, Pt 4, Ch 5, 2 Performance requirements*.

3.1.3 The Naval Administration may impose requirements additional to those in this Chapter.

Section 4
Electric propulsion systems

4.1 General

4.1.1 This Chapter is to be read in accordance with the appropriate Chapters of *Vol 2, Pt 9 Electrotechnical Systems* and *Vol 2, Pt 10 Human Factors*.

4.1.2 Where the arrangements permit a propulsion motor to be connected to a generating plant having a continuous rating greater than the motor rating, means are to be provided to limit the continuous input to the motor to a value not exceeding the continuous full load torque for which the motor and shafts are approved.

4.1.3 The ventilation and cooling systems for electrical propulsion equipment are to be provided with monitoring devices arranged to operate an alarm if the temperature of the heated cooling medium exceeds a predetermined safe value.

4.1.4 The embedded temperature detectors required by *Vol 2, Pt 4, Ch 5, 4.7 Propulsion motors – general 4.7.3* are to be arranged to operate an alarm if the temperature exceeds a predetermined safe value.

4.1.5 Propulsion motors, generators and converters are to be provided with means to prevent the accumulation of moisture and condensate when operating at low power levels, or when idle.

4.2 System design and arrangement

4.2.1 In general, for a ship to be assigned an unrestricted service notation, it is to have two independently driven propellers or other propulsion devices, each connected with at least one electric motor, where these form the sole means of propulsion.

4.2.2 For vessels where a propulsion device driven by electric motors is proposed as the sole means of propulsion, at least two effective, independent electric propulsion motors are to be provided and the system is to be designed in accordance with *Vol 2, Pt 1, Ch 2 Requirements for Machinery and Engineering Systems of Unconventional Design*. A Risk Assessment, in accordance with*Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*, is to identify components where a failure could cause loss of propulsion power or other essential services and the proposed arrangements for preventing and mitigating the effects of such a failure.

4.3 Power requirements

4.3.1 The propulsion system is to have sufficient power for manoeuvring the vessel and for going astern. With the ship travelling at her maximum service speed the propulsion equipment is to be capable of stopping and reversing the ship in an agreed time.

4.3.2 The propulsion system is to have adequate torque and power margins for all operating conditions including manoeuvring and rough weather with due regard to propeller and ship characteristics.

4.3.3 The electric power for the propulsion system may be derived from generating sets dedicated to propulsion duty or from a central power generation plant which serves both propulsion and ship service loads.

4.3.4 Where propulsion power is derived from a central, common, power plant the control system is to ensure a safe distribution of power between propulsion and ship services, with tripping of non-essential loads and/or reduction in propulsion power if necessary.

4.3.5 Where a central power generation system is employed, the number and rating of generator sets is to be such that with one set out of action the remaining sets are capable of providing all essential and normal ship service loads whilst maintaining an effective level of propulsion power.

4.3.6 Where, in a central power generation system, the electrical power requirements are normally supplied by two or more generating sets operating in parallel, on sudden loss of power from one set, the rating of the remaining set(s) in service is to be sufficient to ensure uninterrupted operation of essential services and an effective level of propulsion power.

4.3.7 Where a central power generation system is employed, means are to be provided to connect available generator sets to meet the power requirement of the electric propulsion system. Arrangements are to be in place to prevent generator sets being automatically disconnected during ship manoeuvres.

4.3.8 Where forced cooling is used on propulsion motors, it is to be possible to operate the motor at a defined reduced power level in the event of failure of the forced cooling.

4.3.9 Total harmonic distortion of the a.c. voltage waveform up to 10 per cent on electric propulsion circuits, not directly connected to the main source of electrical power, may be considered where details are submitted which demonstrate that the equipment and systems are capable of operating under such conditions.

4.4 Propulsion control

4.4.1 Propulsion control systems are to be stable throughout their normal operating range and arranged to attenuate any effects of cyclic propeller load fluctuations caused by wave action.

4.4.2 Control of propeller speed, and/or pitch, from zero to full ahead or astern is to be provided.

4.4.3 The control system is to ensure that there is no dangerous overspeeding of propulsion motors upon loss of load.

4.4.4 Interlocks are to be provided in the control system to ensure that ahead and astern circuits are not energised simultaneously.

4.4.5 Any single fault in either the propulsion machine excitation or power distribution systems is not to result in a total loss of propulsion power.

4.4.6 Control, alarm and safety systems for the propulsion system are to satisfy the requirements of *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems* and *Vol 2, Pt 9, Ch 8 Programmable Electronic Systems*.

4.4.7 Each control station is to be provided with an emergency stop function for the propulsion motor(s). The emergency stop function is to be independent of the normal control system.

4.4.8 The control system is to limit the propulsion power if the power available from the generator(s) is not sufficient to supply the demand level of propulsion power. In the event of a power limitation, there is to be a visual indication at the control stations.

4.4.9 Means are to be provided to identify the cause of propulsion motor power limitation or automatic reduction (e.g. excessive load torque, cooling failure, high temperature, power availability).

4.4.10 Alternative means of operation, independent of any remote system, are to be provided to permit effective control of the propulsion equipment for all intended functional requirements. The alternative control facility is to include all necessary protection and power limitation features.

4.4.11 Control systems are not to share hardware or data communication links with control, safety and alarm systems not associated with propulsion control, *see also Vol 2, Pt 9, Ch 8, 5.2 Data communication links*.

4.5 Protection of propulsion system

4.5.1 Provision is to be made for protection against severe overloads, and electrical faults likely to result in damage to plant.

4.5.2 Propulsion motors are to be capable of withstanding, without damage, the thermal and mechanical effects of a short-circuit at the terminals.

4.5.3 Propulsion converters are to be capable of withstanding, without damage, the thermal and mechanical effects of a short-circuit at the terminals or connection to a propulsion motor with a stalled or locked rotor.

4.5.4 Electric motors of podded propulsion units, and/or propulsion motors having permanent magnet excitation, are to be provided with a protective device which, in the event of a short-circuit in the motor or in the cables between the motor and its circuit breaker, will instantaneously open the circuit breaker and, in motors with electromagnetic excitation, de-excite the motor. Motors with permanent magnet main excitation are to be provided with means to prevent further damage as a result of continued rotation after disconnection (e.g. shaft brake).

4.5.5 Safeguards for protecting propulsion equipment against damage resulting from earth faults are to be as specified by the equipment manufacturer. Where the fault current flowing is liable to cause damage to the electrical equipment, there are to be arrangements for interrupting the current automatically.

4.5.6 For the protection of electrical equipment and cables against overvoltages, means are to be provided for limiting the induced voltage when field windings and other inductive circuits are opened. Protective resistors and devices are to be sized to cater for the likely extreme operating conditions.

4.5.7 An alarm is to be initiated when the excitation system of electric generators providing propulsion power is overloaded such that damage due to heating could occur in the generator or its cabling.

4.5.8 Where, on stopping or reversing the propeller, regenerated energy is produced by the propulsion motor, this is not to cause a dangerous increase of speed in the prime mover or a dangerous overvoltage condition on the supply system. Where a central power generation system is used, then the voltage and frequency fluctuations are not to exceed the limits given in *Vol 2, Pt 9, Ch 1, 2 System level requirements*.

4.5.9 Dynamic braking resistors are to be suitably rated for their expected operation.

4.5.10 Loss of flow of air or liquid cooling of propulsion converters, where used, is to initiate an alarm at an attended control position. Loss of flow of air or liquid cooling is not to result in immediate damage to the propulsion converter, *see Vol 2, Pt 9, Ch 3, 7.2 Semiconductor converters 7.2.4*.

4.5.11 Alarms and safeguards for electric propulsion equipment are indicated in *Table 5.4.1 Electric propulsion equipment: Alarms and safeguards*.

Table 5.4.1 Electric propulsion equipment: Alarms and safeguards

Item	Alarm	Note
Electric propulsion equipment ventilation and cooling medium temperature	High	*See Vol 2, Pt 4, Ch 5, 4.1 General 4.1.3* and *Vol 2, Pt 4, Ch 5, 4.3 Power requirements 4.3.8*
Electric propulsion transformer winding temperature	High	*See Vol 2, Pt 9, Ch 3, 7.1 Transformers 7.1.1*
Electric propulsion generator excitation	Overload	*See Vol 2, Pt 4, Ch 5, 4.5 Protection of propulsion system 4.5.7*
Electric propulsion generators and motors winding temperature	High	*See Vol 2, Pt 4, Ch 5, 4.1 General 4.1.4*
Electric propulsion generator and motor lubricating oil temperature	High	*See Vol 2, Pt 4, Ch 5, 4.7 Propulsion motors – general 4.7.7* and *Vol 2, Pt 9, Ch 2, 6.1 General requirements 6.1.4*

Electric propulsion generator and motor lubricating oil supply pressure	Low	*See Vol 2, Pt 4, Ch 5, 4.7 Propulsion motors – general 4.7.6* and *Vol 2, Pt 9, Ch 2, 6.1 General requirements 6.1.5*
Power limitation	—	Indication, *see Vol 2, Pt 4, Ch 5, 4.4 Propulsion control 4.4.8* and *Vol 2, Pt 4, Ch 5, 4.4 Propulsion control 4.4.9*
Note *See also* IEC 60092-501:2013 Annex A.		

4.6 Instruments

4.6.1 The main control station is to be provided with indicating instruments or other means of continuously monitoring the following:

(a) a.c. systems
- (i) The line current and excitation current of each generator, propulsion motor and propulsion transformer primary; and for each generator, the voltage, power and frequency.
- (ii) The winding, bearings and cooling system temperature of each generator, propulsion transformer and propulsion motor.

(b) d.c. systems
- (i) The armature voltage and current for each generator and propulsion motor and the current in each excitation circuit.

4.6.2 Each control station is to be provided with instruments to indicate:

(a) propeller speed;
(b) direction of rotation for a fixed pitch propeller or pitch position for a controllable pitch propeller;
(c) visual indication of power limitation; and
(d) the station in control.

4.7 Propulsion motors – general

4.7.1 Propulsion motors are to comply with the general requirements as specified within *Vol 2, Pt 4, Ch 3, 6.1 General*.

4.7.2 Shaft materials for electric propulsion motors are to comply with the *Rules for Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) and are to be manufactured under LR survey.

4.7.3 Propulsion motors that form part of the electrical propulsion systems are to have at least one embedded temperature detector (ETD) in each phase of the machine winding in locations which may be subjected to the highest temperature. Where there are two coil sides per slot the ETD's are to be located between the insulated coil sides in the slot, *see Vol 2, Pt 4, Ch 5, 4.1 General 4.1.4*.

4.7.4 The adverse effect of voltage stresses on the winding insulation caused by the operation of switching devices is to be taken into account in the specification, design and installation of inverter fed induction motors.

4.7.5 A high bearing temperature alarm is to be provided where the electric propulsion motors are supplied with forced lubrication.

4.7.6 A low lubricating oil pressure alarm is to be provided for electric propulsion motors that are supplied with forced lubrication.

4.7.7 A high lubricating oil temperature alarm is to be provided for electric propulsion motors that are supplied with forced lubrication.

4.8 Propulsion motor ratings

4.8.1 For propulsion motor ratings the applicable requirements of *Vol 2, Pt 9, Ch 3, 6.2 Ratings* are to be complied with.

4.8.2 Synchronous propulsion motors are to be capable of an overload power of not less than 10 per cent at their rated power factor for a period of 15 minutes without injurious heating.

4.9 Propulsion motor temperature rise

4.9.1 For propulsion motor temperature rise the applicable requirements of *Vol 2, Pt 9, Ch 3, 6.3 Temperature rise* are to be complied with.

4.10 Propulsion motor overloads

4.10.1 Machines are to withstand on test, without injury, the following momentary overloads:

(a) The overload tests for propulsion machines will be specially considered for each installation.

4.11 Propulsion motor enclosure

4.11.1 For propulsion motor enclosures the applicable requirements of *Vol 2, Pt 9, Ch 3, 6.5 Machine enclosure* are to be complied with.

4.12 Survey and testing

4.12.1 For survey and testing of propulsion systems the applicable requirements of *Vol 2, Pt 9, Ch 1, 1.6 Surveys* and *Vol 2, Pt 9, Ch 3, 6.7 Survey and testing* are to be complied with.

■ Section 1 General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of *Vol 2, Pt 1 General Requirements*, *Vol 2, Pt 2 Prime Movers*, *Vol 2, Pt 3 Transmission Systems* and *Vol 2, Pt 4 Propulsion Devices*.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to the following systems:

(a) Main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.
(b) Machinery driven at constant speed by oil engines, developing 110 kW and over, for other Mobility and/or Ship Type systems including generator sets which are the source of power for main electric propulsion motors.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, *P*, in kW, and revolutions per minute, *R*, are referred to, the values to be used are those defined in *Vol 2, Pt 1, Ch 3, 4.3 Power ratings*.

1.3 Basic requirements

1.3.1 System designs are to take account of the potential effects of engine and component malfunction and variability in characteristic values.

1.3.2 Where torques, stresses or amplitudes are found to exceed the limits for continuous operation, restrictions in speed and/or power will be imposed.

1.3.3 Where significant changes are subsequently made to a dynamic system which has been approved, (e.g. by changing the original design parameters of the prime movers and/or propulsion shafting system or by fitting a propeller or flexible coupling of different design from the previous), the submission of revised calculations may be required. Details of all such changes are to be submitted for consideration.

■ Section 2 Documentation required for design review

2.1 Documentation

2.1.1 Torsional vibration calculations, including an analysis of the vibratory torques and stresses for the full dynamic system.

2.1.2 Particulars of the division of power and utilisation, throughout the speed range, for turbines, multi-engine or other combined power installations, and those with power take-off systems. For multi-engined installations, special considerations associated with the possible variations in the mode of operation and phasing of engines.

2.1.3 Enginebuilder's harmonic torque data used in the torsional vibration calculations, *see Vol 2, Pt 5, Ch 1, 2.2 Scope of calculations 2.2.3*.

2.1.4 Details of operating conditions encountered in service for prolonged periods, e.g. idling speed, combinator characteristics for installations equipped with controllable pitch propellers.

2.1.5 Details, obtained from the manufacturers, of the principal characteristics of machinery components such as dampers and couplings, confirming their capability to withstand the effects of vibratory loading including, where appropriate, heat dissipation. Evidence that the data which is used to represent the characteristics of components, which has been quoted from other sources, is supported by a programme of physical measurement and control.

2.1.6 Where installations include electric motors, generators or non-integral pumps, drawings showing the principal dimensions of the shaft, together with the manufacturer’s estimates of mass moment of inertia for the rotating parts.

2.1.7 Details of vibration or performance monitoring proposals where required.

2.2 Scope of calculations

2.2.1 Calculations are to be carried out, by recognised techniques, for the full dynamic system formed by the oil engines, turbines, motors, generators, flexible couplings, gearing, shafting and propeller, where applicable, including all branches.

2.2.2 Calculations are to give due consideration to the potential deviation in values used to represent component characteristics due to manufacturing/service variability.

2.2.3 The calculations carried out on oil engine systems are to be based on the Enginebuilders’ harmonic torque data. The calculations are to take account of the effects of engine malfunction commonly experienced in service, such as a cylinder not firing (i.e. no injection but with compression) giving rise to the highest torsional vibration stresses in the shafting. Calculations are also to take account of a degree of imbalance between cylinders, characteristic of the normal operation of an engine under service conditions.

2.2.4 Whilst limits for torsional vibration stress in crankshafts are no longer stated explicitly, calculations are to include estimates of crankshaft stress at all designated operating/service speeds, as well as at any major critical speed.

2.2.5 Calculations are to take into account the possible effects of excitation from propeller rotation. Where the system shows some sensitivity to this phenomenon, propeller makers’ data should be used as a basis for calculation, and submitted.

2.2.6 Where the torsional stiffness of flexible couplings varies with torque, frequency or speed, calculations should be representative of the appropriate range of effective dynamic stiffness.

■ *Section 3*
Design

3.1 Symbols and definitions

3.1.1 The symbols used in this Section are defined as follows:

d = minimum diameter of shaft considered, in mm

$d_{\rm i}$ = diameter of internal bore, in mm

r = ratio $N/N_{\rm s}$ or $N_{\rm c}/N_{\rm s}$ whichever is applicable

N = engine speed, in rev/min

$N_{\rm c}$ = critical speed, in rev/min

$N_{\rm s}$ = maximum continuous engine speed, in rev/min, or, in the case of constant speed generating sets, the full load speed, in rev/min

$Q_{\rm s}$ = rated full load mean torque, in N mm

τ_c = permissible stress due to torsional vibrations for continuous operation, in N/mm2

τ_t = permissible stress due to torsional vibrations for transient operation, in N/mm^2

σ_u = specified minimum tensile strength of the shaft material, in N/mm^2

C_k = a factor for different shaft design features, *see Table 1.3.1 Ck factors*

C_d = a size factor defined as 0,35 + 0,93$d^{-0,2}$

k = the factor used in determining minimum shaft diameter, defined in *Vol 2, Pt 3, Ch 2, 4.2 Intermediate shafts 4.2.1* and *Vol 2, Pt 3, Ch 2, 4.4 Screwshafts and tube shafts 4.4.3*.

e = slot width, in mm.

l = slot length, in mm.

3.1.2 Alternating torsional vibration stresses are to be based on half-range amplitudes of stress resulting from the alternating torque (which is superimposed on the mean torque) representing the synthesis of all harmonic orders present.

3.1.3 All vibration stress limits relate to the synthesis or measurement of total nominal torsional stress and are to be based on the plain section of the shafting neglecting stress raisers.

Table 1.3.1 C_k factors

Intermediate shafts with	
Integral coupling flange and straight sections	1,0
Shrink fit coupling	1,0
Keyway, tapered connection	0,60
Keyway, cylindrical connection	0,45
Radial hole	0,50
Longitudinal slot	0,30 (see 3.1.4)
Thrust shafts external to engines	
On both sides of thrust collar	0,85
In way of axial bearing where a roller bearing is used as a thrust bearing	0,85
Propeller shafts	
Flange mounted or keyless taper fitted propellers	0,55
Key fitted propellers	0,55
Between forward end of aft most bearing and forward stern tube seal	0,80
NOTE The determination of C_k factors for shafts other than shown in this Table will be specially considered by LR.	

3.1.4 For a longitudinal slot C_k = 0,3 is applicable within the dimension limitations given in Pt 3, Ch 2,*Vol 2, Pt 3, Ch 2 Shafting Systems*. If the slot dimensions are outside these limitations, or if the use of another C_k is desired, the actual stress concentration factor (*scf*) is to be documented or determined from *Vol 2, Pt 5, Ch 1, 3.1 Symbols and definitions 3.1.5*, in which case:

$$c_k = \frac{1,45}{scf}$$

Note that the *scf* is defined as the ratio between the maximum local principal stress and $\sqrt{3}$ times the nominal torsional stress (determined for the bored shaft without slots).

3.1.5 Stress concentration factor of slots. The stress concentration factor (*scf*) at the ends of slots can be determined by means of the following empirical formulae:

$$scf = \alpha_{\text{t(hole)}} + 0,57\frac{\frac{\left(l - e_{\text{h}}\right)}{d}}{\left(1 - \frac{d_1}{d}\right)\frac{e_{\text{h}}}{d}}$$

This formula applies to:

- Slots at 120 or 180 or 360 degrees apart.
- Slots with semicircular ends. A multi-radii slot end can reduce the local stresses, but this is not included in this empirical formula.
- Slots with no edge rounding (except chamfering), as any edge rounding increases the *scf* slightly.

$\alpha_{t(hole)}$ represents the stress concentration of radial holes and can be determined as:

$$\alpha_{\text{t(hole)}} = 2,3 - 3\frac{e_{\text{h}}}{d} + 15\left(\frac{e_{\text{h}}}{d}\right)^2 + 10\left(\frac{e_{\text{h}}}{d}\right)^2\left(\frac{d_{\text{i}}}{d}\right)^2$$

where

e_h = hole diameter, in mm

= or simplified to $\alpha_{t(hole)}$ = 2,3.

3.2 Limiting stress in propulsion shafting

3.2.1 The following stress limits apply to intermediate shafts, thrust shafts and to screwshafts fully protected from seawater. For screwshafts, the limits apply to the minimum section between the forward end of the propeller boss and the forward stern gland.

3.2.2 In the case of unprotected screwshafts, special consideration will be given.

3.2.3 In no part of the propulsion shafting system may the alternating torsional vibration stresses exceed the values of τ_c for continuous operation, and τ_t for transient running, given by the following formulae:

For τ_c <0,9:

$$\tau_{\text{c}} = \frac{\sigma_u + 160}{18} C_{\text{k}} C_{\text{d}}\left(3 - 2r^2\right)\text{N/mm}^2$$

$$\tau_{\text{t}} = +1,7\,\tau_{\text{c}}\frac{1}{\sqrt{C_{\text{k}}}}(\text{for } < 0,8)$$

For 0,9 < τ < 1,05:

$$\tau_c = \frac{\sigma_u + 160}{18} C_k C_d\, 1,38\ \text{N/mm}^2$$

3.2.4 In general, the tensile strength of the steel used is to comply with the requirements of *Vol 2, Pt 3, Ch 2 Shafting Systems*. For the calculation of the permissible limits of stresses due to torsional vibration, σ_u is not to be taken as more than 800 N/mm^2 in the case of alloy steel intermediate shafts or 600 N/mm^2 in the case of carbon and carbon-manganese steel intermediate, thrust and propeller shafts.

3.2.5 Where the scantlings of coupling bolts and straight shafting differ from the minimum required by the Rules, special consideration will be given.

3.3 Generator sets

3.3.1 Natural frequencies of the complete set are to be sufficiently removed from the firing impulse frequency at the full load speed, particularly where flexible couplings are interposed between the engine and generator.

3.3.2 Within the speed limits of 0,95N_s and 1,05N_s the vibration stresses in the transmission shafting are not to exceed the values given by the following formula:

$$\tau_c = \pm (21 - 0,014d) \text{ N/mm}^2$$

3.3.3 Vibration stresses in the transmission shafting due to critical speeds which have to be passed through in starting and stopping, are not to exceed the values given by the following formula:

$$\tau_t = 5,5\,\tau_c$$

3.3.4 The amplitudes of total vibratory inertia torques imposed on the generator rotors are to be limited to ±2,0Q_s in general, or to ±2,5Q_s for close-coupled revolving field alternating current generators, over the speed range from 0,95N_s to 1,05N_s. Below 0,95N_s, the amplitudes are to be limited to ±6,0Q_s. Where two or more generators are driven from one engine, each generator is to be considered separately in relation to its own rated torque.

3.3.5 The rotor shaft and structure are to be designed to withstand these magnitudes of vibratory torque. Where it can be shown that they are capable of withstanding a higher vibratory torque, special consideration will be given.

3.3.6 In addition to withstanding the vibratory conditions over the speed range from 0,95N_s to 1,05N_s flexible couplings, if fitted, are to be capable of withstanding the vibratory torques and twists arising from transient criticals and short-circuit currents.

3.3.7 In the case of alternating current generators, resultant vibratory amplitudes at the rotor are not to exceed ±3,5 electrical degrees under both full load working conditions and the malfunction condition mentioned in *Vol 2, Pt 5, Ch 1, 2.2 Scope of calculations 2.2.3*.

3.4 Other auxiliary machinery systems

3.4.1 The relevant requirements of *Vol 2, Pt 5, Ch 1, 3.3 Generator sets 3.3.1*, *Vol 2, Pt 5, Ch 1, 3.3 Generator sets 3.3.2* and *Vol 2, Pt 5, Ch 1, 3.3 Generator sets 3.3.3* are also applicable to other machinery installations such as pumps or compressors.

3.5 Other machinery components

3.5.1 **Torsional vibration dampers.** The use of dampers or detuners to limit vibratory stress due to resonances which occur within the range between 0,85N_s and 1,05N_s is to be considered. If fitted, these should be of a type which makes adequate provision for dissipation of heat. Where necessary, performance monitoring may be required.

3.5.2 **Flexible couplings:**

(a) Flexible couplings included in an installation are to be capable of transmitting the mean and vibratory loads without exceeding the makers' recommended limits for angular amplitude or heat dissipation.
(b) Where calculations indicate that the limits recommended by the manufacturer may be exceeded under misfiring conditions, a suitable means is to be provided for detecting and indicating misfiring. Under these circumstances, power and/or speed restriction may be required. Where machinery is not directly related to Mobility and/or Ship Type, disconnection of the branch containing the coupling would be an acceptable action in the event of misfiring.

3.5.3 **Gearing:**

(a) The torsional vibration characteristics are to comply with the requirements of *Vol 2, Pt 5, Ch 1, 2.2 Scope of calculations*. The vibratory torque should not exceed one third of the full transmission torque throughout the speed range. In cases where the proposed transmission torque loading on the gear teeth is less than the maximum allowable, special consideration will be given the acceptance of additional vibratory loading on the gears.
(b) Where calculations indicate the possibility of torque reversal, the operating speed range is to be determined on the basis of observations during sea trials.

3.6 Restricted speed and/or power ranges

3.6.1 Restricted speed and/or power ranges will be imposed to cover all speeds where the stresses exceed the limiting values, τ_C, for continuous running, including one-cylinder misfiring conditions if intended to be continuously operated under such conditions. For controllable pitch propellers with the possibility of individual pitch and speed control, both full and zero pitch conditions are to be considered. Similar restrictions will be imposed or other protective measures required to be taken, where

vibratory torques or amplitudes are considered to be excessive for particular machinery items. At each end of the restricted speed range, the engine is to be stable in operation.

3.6.2 The restricted speed range is to take account of the tachometer speed tolerances at the barred speeds.

3.6.3 Critical responses which give rise to speed restrictions are to be arranged sufficiently removed from the maximum revolutions per minute to ensure that, in general, at r = 0,8 the stress due to the upper flank does not exceed τ_C.

3.6.4 Provided that the stress amplitudes due to a torsional critical response at the borders of the barred speed range are less than τ_C under normal and stable operating conditions the speed restriction derived from the following formula may be applied:

$$\frac{16}{18-r}N_c \text{ to } \frac{18-r}{16}N_c \text{ inclusive.}$$

3.6.5 Where calculated vibration stresses due to criticals below 0,8N_s marginally exceed τ_C or where the critical speeds are sharply tuned, the range of revolutions restricted for continuous operation may be reduced.

3.6.6 In cases where the resonance curve of a critical speed has been derived from measurements, the range of revolutions to be avoided for continuous running may be taken as that over which the measured stresses are in excess of τ_C, having regard to tachometer accuracy.

3.6.7 Where restricted speed ranges under normal operating conditions are imposed, notice boards are to be fitted at the control stations stating that the engine is not to be run continuously between the speed limits obtained as above, and the engine tachometers are to be marked accordingly.

3.6.8 Where vibration stresses approach the limiting value, τ_t, the range of revolutions restricted for continuous operation may be extended. The notice boards are to indicate that this range must be passed through rapidly.

3.6.9 For excessive vibratory torque, stress or amplitude in other components, bases on *Vol 2, Pt 5, Ch 1, 3.6 Restricted speed and/or power ranges 3.6.1*, the limits of any speed/power restriction are to be such as to maintain acceptable levels during continuous operation.

3.6.10 Where the restrictions are imposed for the contingency of an engine malfunction or component failure, the limits are to be entered in the machinery operating manual.

3.6.11 There are to be no restricted speed ranges imposed above a speed ratio of $r \geq 0,8$ under normal operating conditions.

3.6.12 Restricted speed ranges in one-cylinder misfiring conditions on ships with single engine propulsion are to enable safe navigation whereby sufficient propulsion power is available to maintain control of the ship.

3.7 Tachometer accuracy

3.7.1 Where restricted speed ranges are imposed as a condition of approval, the tachometer accuracy is to be checked against the counter readings, or by equivalent means, in the presence of the Surveyors to verify that it reads correctly within ±2 per cent in way of the restricted range of revolutions.

3.8 Governor control

3.8.1 Where there is significant critical response above and close to the maximum service speed, consideration will be given to the effect of temporary overspeed.

■ *Section 4* Measurements

4.1 General requirements

4.1.1 Where calculations indicate that the limits for torsional vibration within the range of working speeds are exceeded, measurements, using an appropriate technique, may be taken from the machinery installation for the purpose of approval of torsional vibration characteristics, or determining the need for restricted speed ranges and the confirmation of their limits.

4.1.2 Where differences between calculated and measured levels of stress, torque or angular amplitude arise, the stress limits are to be applied to the stresses measured on the completed installation.

4.1.3 The method of measurement is to be appropriate to the machinery components and the parameters which are of concern. Where shaft stresses have been estimated from angular amplitude measurements, and are found to be close to limits, strain gauge techniques may be required. When measurements are required, detailed proposals are to be submitted.

4.2 Vibration monitoring

4.2.1 Where calculations and/or measurements have indicated the possibility of excessive vibratory stresses, torques or angular amplitudes in the event of a malfunction, vibration or performance monitoring, directly or indirectly, may be required.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of *Vol 2, Pt 1 General Requirements*, *Vol 2, Pt 2 Prime Movers*, *Vol 2, Pt 3 Transmission Systems* and *Vol 2, Pt 4 Propulsion Devices*.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, *P*, in kW, and revolutions per minute, *R*, are referred to, the values to be used are those defined in *Vol 2, Pt 1, Ch 3, 4.3 Power ratings*.

1.3 Basic requirements

1.3.1 For all main propulsion systems, the Builders are to ensure that axial vibration amplitudes are satisfactory throughout the speed range. Where natural frequency calculations indicate significant axial vibration responses, sufficiently wide restricted speed ranges will be imposed. Alternatively, measurements may be used to determine the speed ranges at which amplitudes are excessive for continuous running.

■ *Section 2* Documentation required for design review

2.1 Documentation

2.1.1 The results of calculations, together with recommendations for any speed restrictions found necessary.

2.1.2 The Enginebuilder's recommendation for axial vibration amplitude limits.

2.1.3 Estimate of flexibility of the thrust bearing and its supporting structure.

2.2 Scope of calculations

2.2.1 Calculations of axial vibration natural frequency are to be carried out using appropriate techniques, taking into account the effects of flexibility of the thrust bearing, for shaft systems where the propeller is:

(a) Driven directly by a reciprocating internal combustion engine.
(b) Driven via gears, or directly by an electric motor, and where the total length of shaft between propeller and thrust bearing is in excess of 60 times the intermediate shaft diameter.

2.2.2 Where an axial vibration damper is fitted, the calculations are to consider the effect of a malfunction of the damper.

Section 3
Design

3.1 Symbols

3.1.1 The symbols used in this Section are as follows:

D = outside diameter of shaft, taken as an average over length l, in mm

d = internal diameter of shaft, in mm

l = length of shaft line between propeller and thrust bearing, in mm

m = mass of shaft line considered, in kg
= 0,785 ($D^2 - d^2$) Gl

M = dry mass of propeller, in kg

$A = \frac{m}{M}$

M_e = M (A + 2)

n = number of propeller blades

k = estimated stiffness at thrust block bearing, in N/m

E = modulus of elasticity of shaft material, in N/mm^2

G = density of shaft material, in kg/mm^3

N_c = critical speed, in rev/min.

3.2 Critical frequency of axial vibration

3.2.1 For those systems as defined in *Vol 2, Pt 5, Ch 2, 2.2 Scope of calculations 2.2.1* the propeller speed at which the critical frequency occurs may be estimated using the following formula:

$$N_{\mathrm{c}} = \frac{0,98}{n}\left(\frac{ab}{a+b}\right)^{\frac{1}{2}} \mathrm{rev/min}$$

where

$a = \frac{E}{Gl^2}\left(66,2 + 97,5A - 8,88A^2\right)^2 \mathrm{c/min}^2$

$b = 91,2\frac{k}{M_{\mathrm{e}}} \mathrm{c/min}^2$

3.2.2 Where the results of this method indicate the possibility of an axial vibration resonance in the vicinity of the maximum service speed, calculations using a more accurate method will be required.

3.3 Restricted speed ranges

3.3.1 The limits of any speed restriction are to be such as to maintain axial amplitudes within recommended levels during continuous operation.

3.3.2 Limits of a speed restriction, where required, may be determined from calculation or on the basis of measurement.

3.3.3 Where a speed restriction is imposed for the contingency of a damper malfunction, the speed limits are to be entered in the operating manual and regular monitoring of the axial vibration amplitude is required. Details of proposals for monitoring are to be submitted.

■ *Section 4* Measurements

4.1 General requirements

4.1.2 Where calculations indicate the possibility of excessive axial vibration amplitudes within the range of working speeds under normal or malfunction conditions, measurements are required to be taken from the shafting system for the purpose of determining the need for restricted speed ranges.

4.2 Vibration monitoring

4.2.1 Where a vibration monitoring system is to be specified, details of proposals are to be submitted.

Section 1
General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of *Vol 2, Pt 1 General Requirements*, *Vol 2, Pt 2 Prime Movers*, *Vol 2, Pt 3 Transmission Systems* and *Vol 2, Pt 4 Propulsion Devices*.

1.1.2 Unless otherwise advised, it is the responsibility of the Builder as main contractor to ensure, in co-operation with the Enginebuilders, that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

1.1.4 For shafting enclosed within a gearbox, *see Vol 2, Pt 3, Ch 1, 7 Design*.

1.1.5 For diesel engine crankshaft and turbine rotor shafting, *see Vol 2, Pt 2, Ch 1 Reciprocating Internal Combustion Engines*.

1.2 Power ratings

1.2.1 In this Chapter where shaft power, *P*, in kW, and revolutions per minute, *R*, are referred to, the values to be used are those defined in *Vol 2, Pt 1, Ch 3, 4.3 Power ratings*.

1.3 Basic requirements

1.3.1 For all main propulsion shafting systems, the Builders are to ensure that lateral vibration characteristics are satisfactory throughout the speed range.

Section 2
Documentation required for design review

2.1 Documentation

2.1.1 Calculations of the lateral vibration characteristics of shafting systems having supports outboard of the hull or incorporating cardan shafts are to be submitted.

2.2 Calculations

2.2.1 The calculations in *Vol 2, Pt 5, Ch 3, 2.1 Documentation 2.1.1*, taking account of bearing, oil-film (where applicable) and structural dynamic stiffnesses, are to investigate the excitation frequencies which may result in significant amplitudes within the speed range, and are to indicate relative deflections and bending moments throughout the shafting system.

2.2.2 The calculated natural frequencies of the system are to be compared to both the shaft rotational orders and propeller blade passing frequencies. Where cardan shafts are fitted, the shaft second rotational orders are also to be considered.

2.2.3 Requirements for calculations may be waived upon request provided evidence of satisfactory service experience of similar dynamic installations is submitted.

Section 3
Measurements

3.1 General requirements

3.1.1 Where calculations indicate the possibility of significant lateral vibration responses within the range of working speeds, measurements using an appropriate recognised technique may be required to be taken from the shafting system for the purpose of determining that hazardous whirling or excessive vibration does not occur.

3.1.2 The method of measurement is to be appropriate to the machinery arrangement and the modes of vibration which are of concern. When measurements are required, detailed proposals are to be submitted in advance.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Section is to be read in conjunction with the requirements of*Vol 2, Pt 1 General Requirements*, *Vol 2, Pt 2 Prime Movers*, *Vol 2, Pt 3 Transmission Systems* and *Vol 2, Pt 4 Propulsion Devices*.

1.1.2 Unless otherwise advised, it is the responsibility of the Builders as main contractor to ensure, in co-operation with the Enginebuilders that the information required by this Chapter is prepared and submitted.

1.1.3 The requirements of this Chapter are applicable to main propulsion systems formed by oil engines, turbines or electric motors, directly driven or geared to the shafting.

1.2 Basic requirements

1.2.1 For main propulsion installations, the shafting is to be aligned to give reasonable bearing reactions and bending moments, and to meet any specified coupling conditions at the forward end of the shafting at all conditions of vessel loading and operation. The Builder is to position the bearings and construct the bearing seatings to minimise the effects of movements under all operating conditions.

1.2.2 Shaft alignment calculations are to be carried out for main propulsion shafting rotating at propeller speed, including the crankshaft of direct drive systems or the final reduction gear wheel on geared installations. The Builder is to make available shaft alignment procedures detailing the proposed alignment method and checks for these arrangements.

1.2.3 Calculations for single engine geared installations having a screwshaft diameter less than 300 mm are not required.

1.2.4 The shafting systems on naval ships may be required to operate under onerous conditions which may affect the shaft alignment and attention is drawn to ,*Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.16* regarding operation of machinery outside of its optimum envelope.

1.3 Resilient mountings

1.3.1 For resilient mountings, *see Vol 2, Pt 1, Ch 3, 5.7 Ventilation*.

1.4 Flexible couplings

1.4.1 Where the shafting system incorporates flexible couplings, the effects of such couplings on the various modes of vibration are to be considered, *see Vol 2, Pt 5, Ch 2 Axial Vibration*, *Vol 2, Pt 5, Ch 3 Lateral Vibration* and *Vol 2, Pt 5, Ch 4 Shaft Alignment*.

■ *Section 2* Documentation required for design review

2.1 Documentation - Shaft alignment calculations

2.1.1 Shaft alignment calculations are to be submitted to LR for approval for the following shafting systems:

(a) all geared installations, where the screwshaft has a diameter of 300 mm or greater in way of the aftmost bearing;

(b) all geared installations with multiple input/single output, regardless of shaft diameter;
(c) all direct drive installations which incorporate 3 or fewer bearings supporting the intermediate and screwshaft aft of the prime mover;
(d) where prime movers or shaftline bearings are installed on resilient mountings;
(e) all systems where the screwshaft has a diameter of 800 mm or greater in way of the aftmost bearing.

2.1.2 Shaft alignment calculations are to take into account the:

(a) thermal displacements of the bearings between cold static and hot dynamic machinery conditions;
(b) buoyancy effect of the propeller immersion due to the ship's operating draught;
(c) effect of predicted hull deformations over the range of the ship's operating draught, where known;
(d) effect of filling the aft peak ballast tank upon the bearing loads, where known;
(e) gear forces, where appropriate, due to prime-mover engagement on multiple-input single-output installations;
(f) propeller offset thrust effects;
(g) maximum allowed bearing weardown for water or grease-lubricated sterntube bearings, and its effect on the bearing loads.

2.1.3 The shaft alignment calculations are to state the:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the ship's operating profile, for the machinery in cold and hot, static and dynamic conditions;
(b) bearing influence coefficients and the deflection, slope, bending moment and shear force along the shaftline;
(c) details of propeller offset thrust;
(d) details of proposed slope-bore of the aftermost sterntube bearing, where applicable;
(e) manufacturer's specified limits for bending moment and shear force at the shaft coupling of the gearbox/prime movers;
(f) estimated bearing weardown rates for water or greaselubricated sterntube bearings;
(g) expected hull deformation effects and their origin, *viz.* whether finite element calculations or measured results from sister or similar ships have been used;
(h) anticipated thermal rise of prime movers and gearing units between cold static and hot running conditions; and
(i) the manufacturer's allowable bearing loads.

2.2 Shaft alignment procedure

2.2.1 A shaft alignment procedure is to be made available for review and for the information of the attending surveyors for all main propulsion installations detailing, as a minimum:

(a) expected bearing loads at light and normal ballast, fully loaded and any other draughts deemed to be part of the ship's operating profile, for the machinery in cold and hot, static and dynamic conditions;
(b) maximum permissible loads for the proposed bearing designs;
(c) design bearing offsets from the straight line;
(d) design gaps and sags;
(e) location and loads for the temporary shaft supports;
(f) expected relative slope of the shaft and the bearing in the aftermost sterntube bearing;
(g) details of slope-bore of the aftermost sterntube bearing, where applied;
(h) proposed bearing load measurement technique and its estimated accuracy;
(i) jack correction factors for each bearing where the bearing load is measured using a specified jacking technique;
(j) proposed shaft alignment acceptance criteria, including the tolerances; and
(k) flexible coupling alignment criteria.

For water lubricated bearings in sternbushes and sterntubes, details of the piping system and means for verifying that the required water flow specified by the bearing manufacturers is being maintained. *See also Vol 2, Pt 3, Ch 2, 4.16 Sternbushes and sterntube arrangements*.

2.3 Design and installation criteria

2.3.1 For main propulsion installations, the shafting is to be aligned to give, in all conditions of ship loading and machinery operation, bearing load distribution satisfying the requirements of *Vol 2, Pt 5, Ch 4, 2.3 Design and installation criteria 2.3.2*.

2.3.2 Design and installation of the shafting is to satisfy the following criteria:

(a) The Builder is to position the bearings and construct the bearing seatings to minimise the effects of hull deflections under any of the ship's operating conditions with the aim of optimising the bearing load distribution.
(b) Relative slope between the propeller shaft and the aftermost sterntube bearing is, in general, not to exceed 3 x 10^{-4} rad in the static condition.
(c) Sterntube bearing loads are to satisfy the requirements of *Vol 2, Pt 3, Ch 2, 4.16 Sternbushes and sterntube arrangements*.
(d) Bearings of synthetic material are to be verified as being within tolerance for lovality and straightness, circumferentially and longitudinally, after installation.
(e) The sterntube forward bearing static load is to be sufficient to prevent unloading in all static and dynamic operating conditions, including the transient conditions experienced during manoeuvring turns and during operation in heavy weather.
(f) Bearings of synthetic material are to be verified as being within tolerance for diameter, ovalness and straightness after installation.
(g) Intermediate shaft bearings' loads are not to exceed 80 per cent of the bearing manufacturer's allowed maximum load for plain journal bearings, based on the bearing projected area.
(h) Equipment manufacturer's bearing loads are to be within the manufacturer's specified limits, limits, i.e. prime movers, gearing.
(i) Resulting shear forces and bending moments are to meet the equipment manufacturer's specified coupling conditions.
(j) The manufacturer's radial, axial and angular alignment limits for the flexible couplings are to be maintained.

2.4 Measurements

2.4.1 The system bearing load measurements are to be carried out to verify that the design loads have been achieved. In general, the measurements will be carried out by the jack-up measurement technique using calibrated equipment.

2.4.2 For the first vessel of a new design, an agreed programme of static shaft alignment measurements is to be carried out in order to verify that the shafting has been installed in accordance with the design assumptions and to verify the design assumptions in respect of the hull deflections and the effects of machinery temperature changes. The programme is to include static bearing load measurements in a number of selected conditions. Depending on the ship type and the operational loading conditions that are achievable prior to and during sea trials, these should include, where practicable, combinations of light ballast cold, full ballast cold, full ballast hot and full draught hot with aft peak tank empty and full.

2.4.3 For vessels of an existing design or similar to an existing design where evidence of satisfactory service experience is submitted for consideration and for subsequent ships in a series, a reduced set of measurements may be accepted. In such cases, the minimum set of measurements is to be sufficient to verify that the shafting has been installed in accordance with the design assumptions and is to include at least one cold and one hot representative condition.

2.4.4 Where calculations indicate that the system is sensitive to changes in alignment under different service conditions, the shaft alignment is to be verified by measurements during sea trials using an approved strain gauge technique.

■ *Section 3*
Shaft alignment calculation

3.1 Design calculations

3.1.1 The shaft alignment calculations required by *Vol 2, Pt 5, Ch 4, 2.1 Documentation - Shaft alignment calculations 2.1.2* and *Vol 2, Pt 5, Ch 4, 2.1 Documentation - Shaft alignment calculations 2.1.3* are to be in accordance with the requirements of *Vol 2, Pt 5, Ch 4, 3.1 Design calculations 3.1.2* to *Vol 2, Pt 5, Ch 4, 3.1 Design calculations 3.1.5*.

3.1.2 For the purpose of the calculations, the following assumptions are to be made:

(a) The shafting base line, to which all slopes and deflections are to be referred, is to be taken as the nominal centreline of the shafting as shown on the shafting arrangement plan. This is to be established as the line of sight on the vessel.
(b) The centreline of the shaft at the mid-length of the bearing adjacent to the propeller lies on the nominal centreline of the shafting.
(c) The centreline of the shaft at the mid-length of each of the other bearings lies initially on the nominal centreline of the shafting.
(d) The propeller and shaft masses act at right angles to the nominal centreline.
(e) The propeller and shaft weights are reduced due to immersion in water and oil as applicable.

(f) The load distribution in the outboard bearings and sterntube bearings is not uniform along the bearing length.

(g) The load on each plummer and bulkhead bearing is concentrated at the mid-length of the bearing.

3.1.3 The bearing loads corresponding with the shaft centreline at each bearing lying on the nominal centreline of the shafting are to be calculated together with a set of influence coefficients for each bearing. The set of influence coefficients for one bearing is to show for a downwards vertical displacement at that bearing of 0,25 mm, the change in load upon it and upon each of the other bearings.

3.1.4 If the distribution of the bearing loads corresponding with the shaft centreline at each bearing lying on the nominal centreline of the shafting is not acceptable, a satisfactory distribution of load is to be obtained by introducing vertical offsets of the bearings upwards or downwards as necessary.

3.1.5 In some arrangements, the disposition of the main gearbox relative to the nearest plummer block may result in an excessive bending stress in the shaft unless the main gearwheel shaft bearings are assumed to carry the weight of the part of the intervening shafting in addition to the weight of the gearwheel and its shaft. In such arrangements, offsets for the main wheel bearings are to be selected to provide a distribution of load on the main gearwheel forward and aft bearings acceptable to the gearing designer.

3.1.6 Using the selected bearing offsets, the bending moment and deflection diagrams are to be drawn and the slopes through the sterntube and bracket bearings relative to a defined datum established both for as new and for maximum weardown of outboard bearings.

3.1.7 To ensure that the shafting system will be supported at the slope and heights calculated, allowance is to be made for:

(a) Bearing clearances.

(b) Compression of bearing materials under load.

(c) Expansion of bearing material due to immersion in water.

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter apply to the design and construction of steering arrangements and are to be read in conjunction with the requirements for Machinery and Engineering Systems in *Vol 2, Pt 1, Ch 1 General Requirements for Classification of Engineering Systems*and *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*

1.1.2 Consideration will be given to other cases, or to arrangements which are equivalent to those required by the Rules.

1.2 Definitions

1.2.1 **Steering gear control system** means the equipment by which orders are transmitted from the navigating bridge to the steering gear power units. Steering gear control systems comprise transmitters, receivers, hydraulic control pumps and their associated motors, motor controllers, piping and cables.

1.2.2 **Main steering gear** means the machinery, rudder actuator(s), the steering gear power units, if any, and ancillary equipment and the means of applying torque to the rudderstock (e.g. tiller or quadrant) necessary for effecting movement of the rudder for the purpose of steering the ship under normal service conditions.

1.2.3 **Steering gear power unit** means:

(a) in the case of electric steering gear, an electric motor and its associated electrical equipment;
(b) in the case of electro-hydraulic steering gear, an electric motor and its associated electrical equipment and connected pump;
(c) in the case of other hydraulic steering gear, a driving engine and connected pump.

1.2.4 **Auxiliary steering gear** means the equipment other than any part of the main steering gear necessary to steer the ship in the event of failure of the main steering gear but not including the tiller, quadrant or components serving the same purpose.

1.2.5 **Power actuating system** means the hydraulic equipment provided for supplying power to turn the rudder stock, comprising a steering gear power unit or units, together with the associated pipes and fittings, and a rudder actuator. The power actuating systems may share common mechanical components, i.e. tiller quadrant and rudder stock, or components serving the same purpose.

1.2.6 **Maximum ahead service speed** means the maximum service speed which the ship is designed to maintain, at the deepest waterline at maximum propeller RPM and corresponding engine MCR.

1.2.7 **Rudder actuator** means the components which convert directly hydraulic pressure into mechanical action to move the rudder.

1.2.8 **Maximum working pressure** means the maximum expected pressure in the system when the steering gear is operated to comply with *Vol 2, Pt 6, Ch 1, 4.1 General 4.1.2*

1.2.9 **Steering arrangements** means the complete system of components for providing ship directional control.

1.2.10 **Directional control system** means the equipment used to effect changes in ship direction, e.g. the rudder, podded propulsion unit, azimuth thrusters or water jet nozzle. Note that for podded propulsion systems, azimuth thrusters, water jet systems, or other similar systems for effecting changes in ship direction, it is to be assumed that the units must provide thrust in addition to rotation and hence the directional control system must include the propulsion system.

1.3 General

1.3.1 The steering gear is to be secured to the seating by fitted bolts, and suitable chocking arrangements are to be provided. The seating is to be of substantial construction.

1.3.2 The steering gear compartment is to be:

(a) readily accessible and, as far as practicable, separated from machinery spaces; and
(b) provided with suitable arrangements to ensure working access to steering gear machinery and controls. These arrangements are to include handrails and gratings or other non-slip surfaces to ensure suitable working conditions in the event of hydraulic fluid leakage.

■ *Section 2* Documentation required for design review

2.1 Documentation

2.1.1 At least three copies of the plans and information detailed in *Vol 2, Pt 6, Ch 1, 2.2 Plans* and *Vol 2, Pt 6, Ch 1, 2.3 Calculations and information* are to be submitted.

2.2 Plans

2.2.1 Detailed plans of all load bearing, and torque transmitting components and hydraulic pressure retaining parts of the steering system together with proposed rated torque, all relief valve settings and scantlings.

2.2.2 Schematic of the hydraulic system(s), together with pipe material, relief valves and working pressures.

2.2.3 Details of control and electrical aspects.

2.3 Calculations and information

2.3.1 A System Design Description which includes the manoeuvring characteristics for which the ship has been designed.

2.3.2 Where rudder roll stabilisation is specified, details of the system are to be submitted. The control engineering systems are to be in accordance with *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*

2.3.3 Material specifications.

2.3.4 A Risk Assessment (RA) as required by *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems* is to be submitted. The RA is to be in accordance with *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*, is to address the steering system and is to include the following associated sub-systems:

- Hydraulic.
- Securing/mounting.
- Control and monitoring.
- Electrical power supplies.

It is not necessary to consider failure modes relating to the steering gear components.

2.3.5 Noise and vibration acceptance levels for the steering equipment and compartment defined, where applicable.

Section 3
Materials

3.1 General

3.1.1 All components used in steering arrangements for ship directional control are to be of sound reliable construction to the Surveyor's satisfaction.

3.1.2 All components transmitting mechanical forces to the rudder stock are to be tested according to the requirements of *Vol 2, Pt 2 Prime Movers*.

3.1.3 Ram cylinders; pressure housings of rotary vane type actuators, hydraulic power piping, valves, flanges and fittings; and all steering gear components transmitting mechanical forces to the rudder stock (such as tillers, quadrants, or similar components) are to be of steel or other approved ductile material, duly tested in accordance with the requirements of *Vol 2, Pt 2 Prime Movers*. In general, such material is to have an elongation of not less than 12 per cent nor a tensile strength in excess of 650 N/mm^2. Special consideration will be given to the acceptance of grey cast iron for valve bodies and redundant parts with low stress levels.

3.1.4 Where appropriate, consideration will be given to the acceptance of non-ferrous material.

Section 4
Performance

4.1 General

4.1.1 Unless the main steering arrangements for ship directional control comprise two or more identical power units, in accordance with *Vol 2, Pt 6, Ch 1, 4.1 General 4.1.4*, every ship is to be provided with main steering arrangements and auxiliary steering arrangements in accordance with the requirements of the Rules. The main and auxiliary steering arrangements are to be so arranged that the failure of one of them will not render the other one inoperative.

4.1.2 The main steering arrangements for ship directional control are to be:

(a) of adequate strength and capable of steering the ship at maximum ahead service speed which shall be demonstrated in accordance with *Vol 2, Pt 1, Ch 3, 15.4 Testing 15.4.2*;
(b) capable of putting the rudder over from 35° on one side to 35° on the other side with the ship at its deepest seagoing draught and running ahead at maximum ahead service speed and under the same conditions, from 35° on either side to 30° on the other side in not more than 28 seconds;
(c) operated by power where necessary to meet the requirements of (b) and in any case when the Rules, excluding strengthening for navigation in ice, require a rudder stock over 120 mm diameter in way of the tiller; and
(d) so designed that they will not be damaged at maximum astern speed; however, this design requirement need not be proved by trials at maximum astern speed and maximum rudder angle.

4.1.3 The auxiliary steering arrangements for ship directional control are to be:

(a) of adequate strength and capable of steering the ship at navigable speed and of being brought speedily into action in an emergency;
(b) capable of putting the rudder over from 15° on one side to 15° on the other side in not more than 60 seconds with the ship at its deepest seagoing draught and running ahead at one half of the maximum ahead service speed or 7 knots, whichever is the greater; and
(c) operated by power where necessary to meet the requirements of (b) and in any case when the Rules, excluding strengthening for navigation in ice, require a rudder stock over 230 mm diameter in way of the tiller.

4.1.4 Where the main steering arrangements for ship directional control comprise two or more identical power units, auxiliary steering arrangements need not be fitted, provided that the main steering arrangements are capable of operating the ship's directional control system as required by *Vol 2, Pt 6, Ch 1, 4.1 General 4.1.2* while any one of the power units is out of operation.

4.1.5 Main and auxiliary steering gear power units are to be:

(a) Arranged to re-start automatically when power is restored after power failure.

(b) Capable of being brought into operation from each steering position. In the event of a power failure to any one of the steering gear power units, an audible and visual alarm is to be given at each steering position.

(c) Arranged so that transfer between units can be readily effected.

4.1.6 Where the steering arrangements are such that more than one power or control system can be simultaneously operated, the risk of hydraulic locking caused by a single failure is to be considered.

4.1.7 A means of communication is to be provided between the navigating bridge and the steering gear compartment.

4.1.8 Steering gear, other than of the hydraulic type, will be accepted provided the standards are considered equivalent to the requirements of this Section.

4.1.9 Manually operated gears are only acceptable when the operation does not require an effort exceeding 16 kg under normal conditions.

4.2 Rudder angle limiters

4.2.1 Power-operated steering gears are to be provided with positive arrangements, such as limit switches, for stopping the gear before the rudder stops are reached. These arrangements are to be synchronised with the gear itself and not with the steering gear control.

■ *Section 5*
Design and construction

5.1 General

5.1.1 Rudder actuators are to be designed in accordance with the relevant requirements of *Vol 2, Pt 8, Ch 2 Other Pressure Vessels* for Class I pressure vessels (notwithstanding any exemptions for hydraulic cylinders).

5.1.2 Accumulators, if fitted, are to comply with the relevant requirements of *Vol 2, Pt 8, Ch 2 Other Pressure Vessels*.

5.1.3 The welding details and welding procedures are to be approved. All welded joints within the pressure boundary of a rudder actuator or connecting parts transmitting mechanical loads are to be full penetration type or of equivalent strength.

5.1.4 The construction is to be such as to minimise local concentrations of stress.

5.1.5 The design pressure for calculations to determine the scantlings of piping and other steering gear components subjected to internal hydraulic pressure shall be at least 1,25 times the maximum working pressure to be expected under the operational conditions specified in *Vol 2, Pt 6, Ch 1, 4.1 General 4.1.2*, taking into account any pressure which may exist in the low pressure side of the system. Fatigue criteria may be applied for the design of piping and components, taking into account pulsating pressures due to dynamic loads.

5.1.6 For the rudder actuator, the permissible primary general membrane stress is not to exceed the lower of the following values: or

$$= \frac{\sigma_{\text{B}}}{A} \text{ or } \frac{\sigma_{\text{y}}}{\text{B}}$$

where

$\boldsymbol{\sigma}_{\text{B}}$ = specified minimum tensile strength of material at ambient temperature

$\boldsymbol{\sigma}_{\text{y}}$ = specified minimum yield stress or 0,2 per cent proof stress of the material, at ambient temperature

A and *B* are given by the following Table:

	Wrought steel	*Cast steel*	*Nodular cast iron*
A	3,5	4	5
B	1,7	2	3

5.2 Rudder, rudder stock, tiller and quadrant

5.2.1 For the requirements of rudder and rudder stock, *see Vol 1, Pt 3, Ch 3, 2 Rudders*.

5.2.2 For the requirements of tillers and quadrants including the tiller to stock connection, *see Table 1.5.1 Connection of tiller to stock*.

Table 1.5.1 Connection of tiller to stock

Item	Requirements
(1) Dry fit – tiller to stock (*see also Vol 2, Pt 6, Ch 1, 5.2 Rudder, rudder stock, tiller and quadrant 5.2.3* and *Vol 2, Pt 6, Ch 1, 5.2 Rudder, rudder stock, tiller and quadrant 5.2.4*)	(a) For keyed connection, factor of safety against slippage, S = 1,0 The maximum stress in the fillet radius of the tiller keyway should not exceed the yield stress (b) For keyless connection, factor of safety against slippage, S = 2,0 The maximum equivalent von Mises stress should not exceed the yield stress For conical sections, the cone taper should be ≤1:15 (c) Coefficient of friction (maximum) = 0,17 (d) Grip stress not to be less than 20 N/mm^2
(2) Hydraulic fit - tiller to stock (*see also Vol 2, Pt 6, Ch 1, 5.2 Rudder, rudder stock, tiller and quadrant 5.2.3* and *Vol 2, Pt 6, Ch 1, 5.2 Rudder, rudder stock, tiller and quadrant 5.2.4*)	(a) For keyed connection, factor of safety against slippage, S = 1,0 The maximum stress in the fillet radius of the tiller keyway should not exceed the yield stress For conical sections, the cone taper should be ≤1:10 (b) For keyless connection, factor of safety against slippage, S = 2,0 The maximum equivalent von Mises stress should not exceed the yield stress For conical sections, the cone taper should be ≤1:15 (c) Coefficient of friction (maximum) = 0,14 (d) Grip stress not to be less than 20 N/mm^2
(3) Ring locking assemblies fit – tiller to stock	(a) Factor of safety against slippage, S = 2,0 The maximum equivalent von Mises stress should not exceed the yield stress (b) Coefficient of friction = 0,12 (c) Grip stress not to be less than 20 N/mm^2

(4) Bolted tiller and quadrant (this arrangement could be accepted provided the proposed rudder stock diameter in way of tiller does not exceed 350 mm diameter) (*see* Symbols)	Shim to be fitted between two halves before machining to take rudder stock, then removed prior to fitting Minimum thickness of shim, For 4 connecting bolts: $t_s = 0{,}0014\ \delta_{su}$ mm For 6 connecting bolts: $t_s = 0{,}0012\ \delta_{su}$ mm Key(s) to be fitted Diameter of bolts, $\delta_T = \frac{0{,}60\ \delta_{su}}{\sqrt{n_T}}\ mm$ A predetermined setting-up load equivalent to a stress of approximately 0,7 of the yield strength of the bolt material should be applied to each bolt on assembly. A lower stress may be accepted provided that two keys, complying with item (5), are fitted. Distance from centre of stock to centre of bolts should generally be equal to $\delta_{su}\left(1{,}0 + \frac{0{,}30}{\sqrt{n_T}}\right)$ Thickness of flange on each half of the bolted tiller ≥ $\frac{0{,}30}{n_T}$ mm
(5) Key/keyway (*see* Symbols)	Effective sectional area of key in shear ≥0,25 δ_{su}^2 mm^2 Key thickness ≤ 0,17 δ_{su} mm Keyway is to extend over full depth of tiller and is to have a rounded end. Keyway root fillets are to be provided with suitable radii to avoid high local stress
(6) Section modulus – tiller arm (at any point within its length about vertical axis) (*see* Symbols)	To be not less than the greater of: (a) $Z_{TA} = \frac{0{,}15\ \delta_{su}^3 (b_T - bs)}{1000 b_T} \mathrm{cm}^3$ (b) $Z_{TA} = \frac{0{,}06\ \delta_{su}^3 (b_T - 0{,}9\ \delta_{su})}{1000 b_T} \mathrm{cm}^3$ If more than one arm is fitted, combined modulus is to be not less than the greater of (a) or (b) For solid tillers, the breadth to depth ratio is not to exceed 2
(7) Boss (*see* Symbols)	Depth of boss ≥ δ_{su} Thickness of boss in way of tiller ≥ 0,4δ_{su}
Symbols	

b_s = distance between the section of the tiller arm under consideration and the centre of the rudder stock, in mm

NOTE: b_T and b_s are to be measured with zero rudder angle

b_T = distance from the point of application of the load on the tiller to the centre of the rudder stock, in mm

n_T = number of bolts in the connection flanges, but generally not to be taken greater than six

t_s = thickness of shim for machining bolted tillers and quadrants, in mm

Z_{TA} = section modulus of tiller arm, in cm^3

δ_{su} = Rule rudderstock diameter in way of tiller (*see Vol 1, Pt 3, Ch 3 Ship Control Systems*)

δ_T = diameter of bolts securing bolted tillers and quadrants, in mm

5.2.3 The factor of safety against slippage, S (i.e. for torque transmission by friction) is generally based on

$$S = \frac{\text{the torque transmissible by friction}}{M}$$

where M is the maximum torque at the relief valve pressure which is generally equal to the design torque as specified by the steering gear manufacturer.

5.2.4 For conical sections, S is based on the following equation:

$$S = \frac{\mu A \sigma_{\text{r}}}{\sqrt{\left(W + A\ \sigma_{\text{r}} \theta\right)^2 + Q^2}}$$

where

A = interfacial surface area, in mm^2

W = weight of rudder and stock, if applicable, when tending to separate the fit, in N

Q = shear force = $\dfrac{2M}{d_{\text{m}}}$ in N

= where d_m in mm is the mean contact diameter of tiller/stock interface and M, in Nmm is defined in *Vol 2, Pt 6, Ch 1, 5.2 Rudder, rudder stock, tiller and quadrant 5.2.3*

θ = cone taper half angle in radians (e.g. for cone taper 1:10, θ = 0,05)

μ = coefficient of friction

σ_r = radial interfacial pressure or grip stress, in N/mm^2.

5.3 Components

5.3.1 Special consideration is to be given to the suitability of any component necessary for the operation of the steering gear which is not duplicated. Any such component shall, where appropriate, utilise anti-friction bearings such as ball bearings, roller bearings or sleeve bearings which shall be permanently lubricated or provided with lubrication fittings.

5.3.2 All steering gear components transmitting mechanical forces to the rudder stock, which are not protected against overload by structural rudder stops or mechanical buffers, are to have a strength at least equivalent to that of the rudder stock in way of the tiller.

5.3.3 Actuator oil seals between non-moving parts, forming part of the external pressure boundary, are to be of the metal upon metal type or of an equivalent type.

5.3.4 Actuator oil seals between moving parts, forming part of the external pressure boundary, are to be duplicated, so that the failure of one seal does not render the actuator inoperative. Alternative arrangements providing equivalent protection against leakage may be accepted.

5.3.5 Piping, joints, valves, flanges and other fittings are to comply within the requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements* for Class I piping systems components. The design pressure is to be in accordance with *Vol 2, Pt 6, Ch 1, 5.1 General 5.1.5*

5.3.6 Hydraulic power operated steering gear is to be provided with the following:

(a) Arrangements to maintain the cleanliness of the hydraulic fluid, taking into consideration the type and design of the hydraulic system.
(b) A fixed storage tank having sufficient capacity to recharge at least one power actuating system including the reservoir, where the main steering gear is required to be power operated. The storage tank is to be permanently connected by piping in such a manner that the hydraulic systems can be readily recharged from a position within the steering gear compartment and provided with a contents gauge.

5.4 Valve and relief valve arrangements

5.4.1 For vessels with non-duplicated actuators, isolating valves are to be fitted at the connection of pipes to the actuator, and are to be directly fitted on the actuator.

5.4.2 Arrangements for bleeding air from the hydraulic system are to be provided, where necessary.

5.4.3 Relief valves are to be fitted to any part of the hydraulic system which can be isolated and in which pressure can be generated from the power source or from external forces. The settings of the relief valves is not to exceed the design pressure. The valves are to be of adequate size and so arranged as to avoid an undue rise in pressure above the design pressure.

5.4.4 Relief valves for protecting any part of the hydraulic system which can be isolated, as required by *Vol 2, Pt 6, Ch 1, 5.4 Valve and relief valve arrangements 5.4.3*, are to comply with the following:

(a) The setting pressure is not to be less than 1,25 times the maximum working pressure.
(b) the minimum discharge capacity of the relief valve(s) is not to be less than 110 per cent of the total capacity of the pumps which can deliver through it (them). Under such conditions the rise in pressure is not to exceed 10 per cent of the setting pressure. In this regard, due consideration is to be given to extreme foreseen ambient conditions in respect of oil viscosity.

5.5 Flexible hoses

5.5.1 Hose assemblies approved by Lloyd's Register LR may be installed between two points where flexibility is required but are not to be subjected to torsional deflection (twisting) under normal operating conditions. In general, the hose should be limited to the length necessary to provide for flexibility and for proper operation of machinery, *see also Vol 2, Pt 7, Ch 1, 13 Flexible hoses*.

5.5.2 Hoses should be high pressure hydraulic hoses according to recognised Standards and suitable for the fluids, pressures, temperatures and ambient conditions in question.

5.5.3 Burst pressure of hoses is to be not less than four times the design pressure.

5.6 Noise and vibration

5.6.1 The reduction of airborne noise, and the structural vibration caused by the steering equipment, is to be regarded as an essential part of the design. The noise and vibration acceptance levels are normally specified for each ship. The techniques to be employed to achieve this are:

(a) Reduction of noise and vibration at source.
(b) Control of noise and vibration transmission paths by use of vibration mounting systems, structural damping, hydraulic silencers and flexible pipes.

5.6.2 All possible noise and vibration transmission paths are to be considered to eliminate noise shorts.

Section 6
Steering control systems

6.1 General

6.1.1 Steering gear control is to be provided:

(a) For the main steering gear, both on the navigating bridge and in the steering gear compartment.
(b) Where the main steering gear is arranged according to *Vol 2, Pt 6, Ch 1, 4.1 General 4.1.4*, by two independent control systems, both operable from the navigating bridge. This does not require duplication of the steering wheel or steering lever. Where the control system consists of a hydraulic telemotor, a second independent system need not be fitted.
(c) For the auxiliary steering gear, in the steering gear compartment and, if power operated, it shall also be operable from the navigating bridge and is to be independent of the control system for the main steering gear.
(d) Where the steering gear is so arranged that more than one control system can be simultaneously operated, the risk of hydraulic locking caused by single failure is to be considered.

6.1.2 Any main and auxiliary steering gear control system operable from the navigating bridge is to comply with the following:

(a) Means are to be provided in the steering gear compartment for disconnecting any control system operable from the navigating bridge from the steering gear it serves.
(b) The system is to be capable of being brought into operation from a position on the navigating bridge.

6.1.3 The angular position of the rudder shall:

(a) If the main steering gear is power operated, be indicated at all conning positions. The rudder angle indication is to be independent of the steering gear control system.
(b) Be recognisable in the steering gear compartment.

6.1.4 Appropriate operating instructions with a block diagram showing the change-over procedures for steering gear control systems and steering gear actuating systems are to be permanently displayed in the wheel-house and in the steering gear compartment.

6.1.5 Where the system failure alarms for hydraulic lock (*see Table 1.8.1 Alarms*) are provided, appropriate instructions shall be placed on the navigating bridge to shut down the system at fault.

Section 7
Electrical power circuits and equipment

7.1 Electric power circuits, electric control circuits, monitoring and alarms

7.1.1 Short circuit protection, an overload alarm and, in the case of polyphase circuits, an alarm to indicate single phasing are to be provided for each main and auxiliary motor circuit. Protective devices are to operate at not less than twice the full load current of the motor or circuit protected and are to allow excess current to pass during the normal accelerating period of the motors.

7.1.2 Where steering gear motor circuits are supplied by converters, consideration will be given to arrangements that provide an equivalent level of safety, reliability, availability and indication to those specified in *Vol 2, Pt 6, Ch 1, 7.1 Electric power circuits, electric control circuits, monitoring and alarms 7.1.1*, provided that a technical justification is submitted.

7.1.3 The alarms required by *Vol 2, Pt 6, Ch 1, 7.1 Electric power circuits, electric control circuits, monitoring and alarms 7.1.1* are to be provided on the bridge and in the main machinery space or control room from which the main machinery is normally controlled.

7.1.4 Indicators for running indication of each main and auxiliary motor are to be installed on the navigating bridge and at a suitable main machinery control position.

7.1.5 A low-level alarm is to be provided for each power actuating system hydraulic fluid reservoir to give the earliest practicable indication of hydraulic fluid leakage. Alarms are to be given on the navigation bridge and in the machinery space where they can be readily observed.

7.1.6 Two exclusive circuits are to be provided for each electric or electrohydraulic steering gear arrangement consisting of one or more electric motors.

7.1.7 Each of these circuits is to be fed from the main switchboard. One of these circuits may pass through the emergency switchboard.

7.1.8 One of these circuits may be connected to the motor of an associated auxiliary electric or electrohydraulic power unit.

7.1.9 Each of these circuits is to have adequate capacity to supply all the motors which can be connected to it and which can operate simultaneously.

7.1.10 These circuits are to be separated throughout their length as widely as is practicable.

7.1.11 Where specified and agreed, in ships of category NS3, if an auxiliary steering gear is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard. Consideration would be given to other protective arrangements than described in *Vol 2, Pt 6, Ch 1, 7.1 Electric power circuits, electric control circuits, monitoring and alarms 7.1.1*, for such a motor primarily intended for other services.

7.2 Electric control circuits

7.2.1 Electric control systems are to be independent and separated as far as is practicable throughout their length.

7.2.2 Each main and auxiliary electric control system which is to be operated from the navigating bridge is to comply with the following:

(a) It is to be served with electric power by a separate circuit supplied from the associated steering gear power circuit, from a point within the steering gear compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering gear power circuit is connected.
(b) Each separate circuit is to be provided with short circuit protection only.

■ *Section 8* Monitoring and alarms

8.1 Monitoring

8.1.1 Alarms and monitoring requirements are indicated in *Vol 2, Pt 6, Ch 1, 8.1 Monitoring 8.1.2* and *Table 1.8.1 Alarms*.

Table 1.8.1 Alarms

Item	Alarm	Note
Angular position of the steering mechanism	—	Indication, *see Vol 2, Pt 6, Ch 1, 8.1 Monitoring 8.1.2*
	Failure	*See Vol 2, Pt 6, Ch 1, 8.1 Monitoring 8.1.4*
Steering power units, power	Failure	—
Steering motors	Overload Single phase	For alarm and running indication locations, *see Vol 2, Pt 6, Ch 1, 7.1 Electric power circuits, electric control circuits, monitoring and alarms 7.1.3* and *Vol 2, Pt 6, Ch 1, 7.1 Electric power circuits, electric control circuits, monitoring and alarms 7.1.4*
Control system power	Failure	—
Steering gear hydraulic oil tank level	Low	Each reservoir to be monitored. For alarm locations, *see Vol 2, Pt 6, Ch 1, 7.1 Electric power circuits, electric control circuits, monitoring and alarms*
Auto pilot	Failure	Running indication

Hydraulic oil temperature	High	Where oil cooler is fitted
Hydraulic lock	Fault	Where more than one system (either power or control) can be operated simultaneously each system is to be monitored, *see* Note 1
Hydraulic oil filter differential pressure	High	When oil filters are fitted
Control system	Failure	*See Vol 2, Pt 6, Ch 1, 8.1 Monitoring 8.1.4*

NOTE
1. This alarm is to identify the system at fault and to be activated when (for example):

- Position of the variable displacement pump control system does not correspond with given order; or
- incorrect position of 3-way full flow valve or similar in constant delivery pump system is detected.

8.1.2 The angular position of the steering mechanism is to:

(a) Where the main steering unit is power operated, be indicated at the control station, and other positions as applicable. The angular indication is to be independent of the steering unit control system; and is to indicate any abnormal responses or malfunctions. The logic of such feedback and indications is to be consistent with the other alarms and indications so that in an emergency operators are unlikely to be confused.
(b) Be recognisable in the steering unit compartment, if applicable.

8.1.3 The alarms described in *Table 1.8.1 Alarms* are to be indicated on the navigating bridge and the additional locations described and are to be in accordance with the alarm system specified by *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*

8.1.4 Steering control systems are to be monitored and an audible and visual alarm is to be initiated on the navigation bridge in the event of:

- failure of the control system, including command and feedback circuits; or
- unacceptable deviation between the rudder order and actual rudder position and/or unacceptable delay in response to changes in the rudder order.

■ *Section 9* Alternative sources of power and emergency operation

9.1 Alternative sources of power

9.1.1 An alternative power supply, sufficient to supply the steering arrangements which comply with the requirements of *Vol 2, Pt 6, Ch 1, 4.1 General 4.1.2* and also its associated control systems and steering angle indicator, is to be provided automatically, within 45 seconds of loss of the main power supply, either from an emergency or alternative source of electrical power complying with *Vol 2, Pt 10, Ch 1, 4 Verification requirements*or from an independent source of power located in the steering gear compartment. Where an independent source of electrical power located in the steering gear compartment is used as an alternative power supply, this source is to be used only for this purpose.

9.1.2 The alternative power supply shall have a capacity for at least 30 minutes of continuous operation. A greater or lesser period of time may be specified based on the operational requirements of the ship and any assigned Service Restriction.

9.1.3 Where the alternative power source is a generator, or an engine driven pump, starting arrangements are to comply with the requirements relating to the starting arrangements of emergency generators.

9.2 Emergency hand pump operation

9.2.1 Hydraulically operated steering gears are to be provided with an emergency hand pump permanently fitted in a readily accessible position in the steering gear compartment. The pump is to be permanently connected between the reservoir and the main hydraulic system.

9.2.2 The hand pump is to be capable of moving the rudder to mid-position in the absence of electrical power, and being operated by not more than two men. It is to be capable of moving the rudder(s) up to 10° either side at ship speeds up to 10 knots, and 5° at ship speeds above 10 knots.

9.3 Emergency capability

9.3.1 For use in an emergency condition, facilities are to be provided to hydraulically lock the rudder actuators in the mid-position when the pumps are stopped. Isolating valves are to be fitted direct onto the rudder actuators.

9.3.2 An independent means of mechanically restraining the rudder amidships is to be provided.

9.3.3 Where there is more than one rudder fitted, arrangements are to be such that any rudder can be hydraulically and mechanically locked whilst allowing use of the other rudder(s).

■ *Section 1* Scope

1.1 Application

1.1.1 This Chapter applies to all naval ships intended to be classed and covers the design and construction of piping systems, including components and fittings forming part of such systems.

1.1.2 The provisions of this Chapter do not address pipe size selection in respect of adequacy to satisfy design requirements for flow rates and/or heat transfer in piping systems.

1.1.3 The Sections detail information necessary for verifying the adequacy of design in respect of strength and suitability for intended purpose with regard to materials and scantlings.

1.1.4 The materials used for pipes, valves and fittings are to be suitable for the medium and the service for which the piping is intended.

1.1.5 Piping design is to comply with the remainder of this Chapter, as applicable.

Section 2
General

2.1 Documentation required for design review

2.1.1 A System Design Description indicating the following information is to be submitted for each piping system:

Design pressure.

Design temperature.

Class of system.

Internal pipe diameter and thickness.

Material specification.

Corrosion protection.

Corrosion allowance.

Pipe connection specifications.

Valve specifications.

Flexible hose specifications.

Expansion piece specifications.

Details of any other pipe fittings.

Pumping unit type and discharge characteristics.

Testing procedures.

System Design Description for heat exchangers as required by *Vol 2, Pt 7, Ch 1, 18.1 General 18.1.11*.

2.1.2 Where the Owner has specified requirements for the life of a particular piping system under defined operating conditions, details of enhanced pipe scantlings and assumptions made are to be submitted for review.

2.2 Definitions

2.2.1 **Mobility and/or Ship Type piping systems** are those systems installed for the propulsion and safety of the ship (*see Vol 2, Pt 1, Ch 1, 3 Engineering system designation*) and include the following:

Air and overflow arrangements.

Sounding arrangements.

Bilge and dewatering systems.

Ballast systems.

Fuel oil systems.

Gas fuel systems.

Lubricating oil systems.

Thermal oil systems.

Hydraulic oil systems for:

- steering gears;
- controllable pitch propellers;
- thrust units for propulsion;
- windlass machinery;
- watertight bow, stern, side and internal doors;
- valve control systems, etc.

Fresh water cooling systems for machinery.

Sea water cooling systems.

Compressed air systems for starting engines, control and alarms.

Steam and condensate systems.

Exhaust and flue gas systems.

Control systems for remote operation of valves and ventilation flaps.

2.2.2 **Ancillary piping systems** are those systems installed for conditions of habitability and recreation; they include the following:

Heating systems.

Air conditioning systems.

Domestic sanitary and fresh water systems.

2.2.3 **Piping system** includes pipes and fittings such as expansion joints, valves, pipe joints, support arrangements, flexible tube lengths etc. and components in direct connection with the piping such as pumps, heat exchangers, air receivers, independent tanks, etc. It does not include main and auxiliary machinery such as oil engines, steam and gas turbines, boilers, reduction gears, etc.

2.3 Classes of piping system and components

2.3.1 For the purpose of testing the type of joint to be adopted, heat treatment and welding procedure, pipes are subdivided into three classes as indicated in *Table 1.2.1 Classes of piping system*.

Table 1.2.1 Classes of piping system

Piping system	Class II		Class III	
	p	T	p	T
	bar	deg C	bar	deg C
Steam	16,0	300	7,0	170
Thermal oil	16,0	300	7,0	150
Flammable liquids*see* Note	16,0	150	7,0	60
Other media	40,0	300	16,0	200

Note 1. Flammable liquids include: fuel oil; lubricating oil and flammable hydraulic oil.

Note 2. For grey cast iron, *see also Vol 2, Pt 7, Ch 1, 8.2 Grey cast iron 8.2.2*.

2.3.2 Dependent on the service for which they are intended, Class II and Class III piping are not to be used for design pressure or temperature conditions in excess of those shown in *Table 1.2.1 Classes of piping system*. Where either the maximum design pressure or temperature exceeds that applicable to Class II piping systems, Class I piping is to be used. To illustrate, *see Figure 1.2.1 Classes of piping system* P_1 and T_1 correspond to maximum pressures and temperatures for a Class III piping system and P_2 and T_2 to those for a Class II piping system depending on the service.

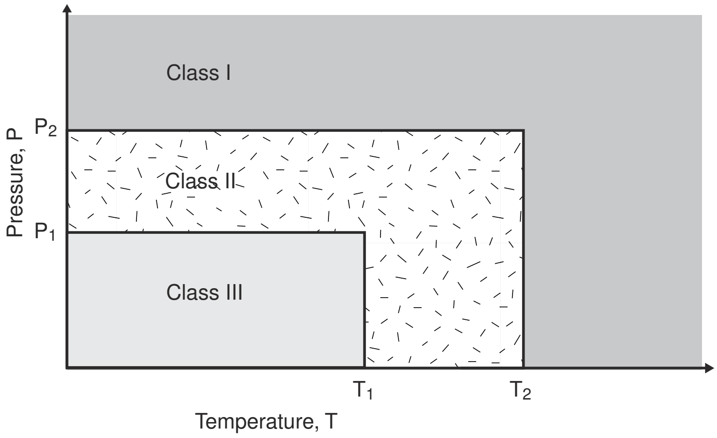


Figure 1.2.1 Classes of piping system

2.3.3 In addition to the pressure piping systems in *Table 1.2.1 Classes of piping system*, Class III pipes may be used for open ended piping, e.g. overflows, vents, open ended drains, etc.

■ *Section 3* **Assessment**

3.1 Design and construction

3.1.1 All piping systems are to be designed and constructed for their intended service and working conditions.

3.1.2 Materials sensitive to heat, such as aluminium and plastics, are not to be used in Mobility systems or Ship Type systems necessary for the safe operation of the ship, or for containing flammable liquids or sea water where leakage or failure could result in fire or in flooding of a watertight compartment.

3.1.3 The strength and construction of pipes, components and fittings is to preclude loss of Mobility and/or Ship Type systems, escape of flammable liquid and flooding.

3.1.4 The selection of pipe connections in piping systems is to recognise the boundary fluids, pressure and temperature conditions and location.

3.1.5 Pipe connections in accordance with national or other approved standards will be accepted where the standards are appropriate to the piping system.

3.1.6 Pipe thicknesses greater than the minimum required by this Chapter may be necessary where the likelihood of erosion cannot be avoided and/or where there is a likelihood of corrosion exceeding the nominal allowances specified in the Rule requirements. Pipe thicknesses may also need to be increased where the Owner has specified requirements for system life, *see Vol 2, Pt 7, Ch 1, 2.1 Documentation required for design review 2.1.2*.

3.2 Design symbols

3.2.1 The symbols used in this Chapter are defined as follows:

a = percentage negative manufacturing tolerance on thickness

c = corrosion allowance, in mm

d = inside diameter of pipe, in mm, *see Vol 2, Pt 7, Ch 1, 3.2 Design symbols 3.2.3*

e = weld efficiency factor, *see Vol 2, Pt 7, Ch 1, 3.2 Design symbols 3.2.4*

p = design pressure, in bar, *see Vol 2, Pt 7, Ch 1, 3.3 Design pressure*

p_t = hydraulic test pressure, in bar

t = the minimum thickness of a straight pipe, in mm, including corrosion allowance and negative tolerance, where applicable

t_b = the minimum thickness of a straight pipe to be used for a pipe bend, in mm, including bending allowance, corrosion allowance and negative tolerance, where applicable

D = outside diameter of pipe, in mm, *see Vol 2, Pt 7, Ch 1, 3.2 Design symbols 3.2.2*

R = radius of curvature of a pipe bend at the centre line of the pipe, in mm

T = design temperature, in °C, *see Vol 2, Pt 7, Ch 1, 3.4 Design temperature*

σ = maximum permissible design stress, in N/mm^2.

3.2.2 The outside diameter, *D*, is subject to manufacturing tolerances, but these are not to be used in the evaluation of formulae.

3.2.3 The inside diameter, *d*, is not to be confused with nominal size, which is an accepted designation associated with outside diameters of standard rolling sizes.

3.2.4 The weld efficiency factor, *e*, is to be taken as 1 for seamless and electric resistance and induction welded steel pipes. Where other methods of pipe manufacture are proposed, the value of *e* will be specially considered.

3.3 Design pressure

3.3.1 The design pressure, *p*, is the maximum permissible working pressure and is to be not less than the highest set pressure of the safety valve or relief valve.

3.3.2 In water tube boiler installations, the design pressure for steam piping between the boiler and integral superheater outlet is to be taken as the design pressure of the boiler, i.e. not less than the highest set pressure of any safety valve on the boiler drum. For piping leading from the superheater outlet, the design pressure is to be taken as the highest set pressure of the superheater safety valves.

3.3.3 The design pressure of feed piping and other piping on the discharge from pumps is to be taken as the pump pressure at full rated speed against a shut valve. Where a safety valve or other protective device is fitted to restrict the pressure to a lower value than the shut valve load, the design pressure is to be the highest set pressure of the device.

3.3.4 For pipes containing heated oil under pressure (temperature 60°C and above and pressure 0,18 bar and above), the design pressure is to be taken as not less than 14 bar.

3.3.5 For design pressure of steering gear components and piping, *see Vol 2, Pt 6, Ch 1 Steering Gear*.

3.4 Design temperature

3.4.1 The design temperature is to be taken as the maximum temperature of the internal fluid, but in no case is to be less than 50°C.

3.4.2 In the case of pipes for superheated steam, the temperature is to be taken as the designed operating steam temperature for the pipeline, provided that the temperature at the superheater outlet is closely controlled. Where temperature fluctuations exceeding 15°C above the designed temperature are to be expected in normal service, the steam temperature to be used for determining the allowable stress is to be increased by the amount of this excess.

3.5 Use of alternative design codes

3.5.1 Where it is proposed to use a material with a minimum specified tensile strength different from that indicated in *Table 1.6.1 Carbon and carbon-manganese steel pipes*, *Table 1.6.2 Alloy steel pipes* or *Table 1.7.1 Copper and copper alloy pipes* and

the material is in accordance with a recognised National/International Standard, the use of alternative design codes for calculating pipe stresses will be accepted. The design code used is to be suitable for the intended application.

3.5.2 Where alternative design codes are used, they are to be stated together with any assumptions made.

■ *Section 4* Materials

4.1 Metallic materials

4.1.1 Materials for Class I and II piping systems and components as defined in *Table 1.2.1 Classes of piping system*, also for shell valves and fittings and fittings on the collision bulkhead, are to be manufactured and tested in accordance with the*Rules for the Manufacture, Testing and Certification of Materials, July 2015* (hereinafter referred to as the Rules for Materials).

4.1.2 Ferrous castings and forgings for Class I and II piping systems are to be produced at a works approved by Lloyd's Register (hereinafter referred to as 'LR').

4.1.3 Materials for Class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable National Standards.

4.1.4 The Manufacturer’s materials certificate will be accepted in lieu of an LR materials certificate for Class III piping systems and for all other classes of piping and associated components where the maximum design conditions are less than the values shown in *Table 1.4.1 Maximum conditions for pipes, valves and fittings for which Manufacturer's materials test certificate is acceptable*. *See Ch 1, 3.1 General 3.1.3* of the Rules for Materials.

Table 1.4.1 Maximum conditions for pipes, valves and fittings for which Manufacturer's materials test certificate is acceptable

Material	*DN* = Nominal diameter, mm P_w = Working pressure, bar
When the working temperature is less than 300°C: Carbon and low alloy steel, austenitic stainless steel and cast iron (spheroidal or nodular)	$DN < 50$ or $P_w \times DN < 2500$
Copper alloy intended for a working temperature of less than 200°C	$DN < 50$ or $P_w \times DN < 1500$

4.1.5 The Manufacturer's certificate validated by LR for materials for ship-side valves and fittings and valves on the collision bulkhead equal to or less than 500 mm nominal diameter will be accepted in lieu of LR's materials certificate where the valves and fittings are in accordance with a recognised National Standard applicable to the intended application and are manufactured and tested in accordance with the appropriate requirements of the Rules for Materials.*See Ch 1, 3.1 General 3.1.3* of the Rules for Materials.

4.2 Non-metallic materials

4.2.1 Pipes and fittings intended for applications in Class I, Class II and Class III systems for which there are Rule requirements are to be manufactured in accordance with *Ch 14 Plastics Materials and other Non-Metallic Materials* of the Rules for Materials.

Section 5
Pipe connections

5.1 General

5.1.1 Connections in piping systems may be made by any of the methods described in this Section, or by special types of approved joints which have been shown to be suitable for the design conditions. Details of connection methods, not described in this Section are to be submitted for consideration.

5.1.2 The selection of pipe connections in piping systems is to recognise the boundary fluids, pressure and temperature conditions, external or cyclic loading and location.

5.1.3 Pipe connections in accordance with national or other established standards will be accepted where the standards are appropriate to the piping system.

5.1.4 The type and location of pipe connections are to recognise the need to facilitate Periodic Survey of piping systems and associated items of machinery and the need for cold 'pull up' if required.

5.1.5 Pipe connections are not to be used to compensate for pipe misalignment.

5.1.6 Piping with joints is to be adequately adjusted, aligned and supported. Supports or hangers are not to be used to force alignment of piping at the point of connection.

5.1.7 Pipes passing through, or connected to, watertight decks are to be continuous or provided with an approved bolted or welded connection to the deck or bulkhead.

5.1.8 For details of non-destructive tests on piping systems, other than hydraulic tests, *see Ch 13 Requirements for Welded Construction* of the Rules for Materials.

5.1.9 The requirements in *Vol 2, Pt 7, Ch 1, 5.2 Flange connections*are applicable to connections in metallic piping systems.

5.2 Flange connections

5.2.1 The dimensions and configuration of flanges and bolting are to be selected in accordance with recognised standards. The dimensions and bolting arrangements of nonstandard flanges will be the subject of special consideration.

5.2.2 Gaskets are to be suitable for the conveyed fluids under design pressure and temperature conditions and their dimensions and configuration is to be in accordance with recognised standards. Gasket materials used in oil piping systems are to be impervious to oil and the thinnest possible as determined from manufacturer's recommendations that the flange arrangement will allow, to ensure the minimum loss of bolt stress due to gasket relaxation.

5.2.3 Acceptable flange pipe connections are indicated in *Figure 1.5.1 Typical welded-on flanges*. Limiting applications of different types of flange connections are indicated in *Table 1.5.1 Limiting design conditions for flange types* depending on the size, pressure and temperature.

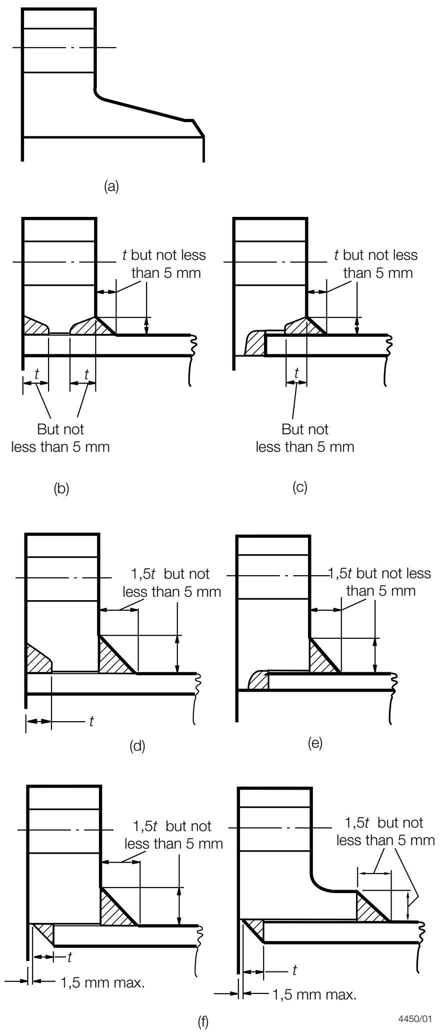


Figure 1.5.1 Typical welded-on flanges

Table 1.5.1 Limiting design conditions for flange types

Flangetype	Maximumpressure	Maximumtemperature	Maximumpipe o.d.	Maximumpipe bore
		°C	mm	mm
(a)	Pressure-temperature ratings to be in accordance with a recognised standard	No restriction	No restriction	No restriction
(b)	Pressure-temperature ratings to be in accordance with a recognised standard	No restriction	168,3 foralloy steels*	No restriction
(c)	Pressure-temperature ratings to be in accordance with a recognised standard	No restriction	168,3 foralloy steels*	75
(d)	Pressure-temperature ratings to be in accordance with a recognised standard	425	No restriction	No restriction
(e)	Pressure-temperature ratings to be in accordance with a recognised standard	425	No restriction	75

(f)	Pressure-temperature ratings to be in accordance with a recognised standard	425	No restriction	No restriction
* No restriction for carbon steels				

5.3 Screwed-on flanges

5.3.1 Where flanges are secured by screwing, as indicated in *Figure 1.5.2 Screwed on flange*, the pipe and flange are to be screwed with a vanishing thread and the diameter of the screwed portion of the pipe over the thread is not to be appreciably less than the outside diameter of the unscrewed pipe. After the flange has been screwed hard home the pipe is to be expanded into the flange.

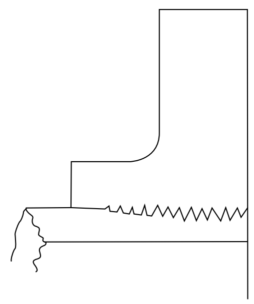


Figure 1.5.2 Screwed on flange

5.3.2 The vanishing thread on a pipe is to be not less than three pitches in length, and the diameter at the root of the thread is to increase uniformly from the standard root diameter to the diameter at the top of the thread. This may be produced by suitably grinding the dies, and the flange should be tapered out to the same formation.

5.3.3 Such screwed and expanded flanges may be used for steam for a maximum design pressure of 30 bar and maximum design temperature of 370°C and for feed for maximum design pressure of 50 bar.

5.4 Welded-on flanges, butt welded joints and fabricated branch pieces

5.4.1 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the pipes are intended.

5.4.2 Butt welded joints are generally to be of the full penetration type and are to meet the requirements of *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

5.4.3 Welded-on flanges are not to be a tight fit on the pipes. The maximum clearance between the bore of the flange and the outside diameter of the pipe is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

5.4.4 Where butt welds are employed in the attachment of flange type (a), in pipe-to-pipe joints or in the construction of branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided that the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to the thickness of the thinner at the butt joint. The welding necks of valve chests are to be sufficiently long to ensure that the valves are not distorted as the result of welding and subsequent heat treatment of the joints.

5.4.5 Where backing rings are used with flange type (a) they are to fit closely to the bore of the pipe and should be removed after welding. The rings are to be made of the same material as the pipes or of mild steel having a sulphur content not greater than 0,05 per cent.

5.4.6 Branches may be attached to pressure pipes by means of welding provided that the pipe is reinforced at the branch by a compensating plate or collar or other approved means, or alternatively that the thickness of pipe and branch are increased to maintain the strength of the pipe. These requirements also apply to fabricated branch pieces.

5.4.7 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but, in general, oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to pipes exceeding 100 mm diameter or 9,5 mm thick. The welding is to be carried out in accordance with the appropriate paragraphs of *Vol 2, Pt 1, Ch 4 Requirements for Fusion Welding of Pressure Vessels and Piping*.

5.5 Loose flanges

5.5.1 Loose flange designs as shown in *Figure 1.5.3 Loose flange arrangements* may be used provided they are in accordance with a recognised National or International Standard.

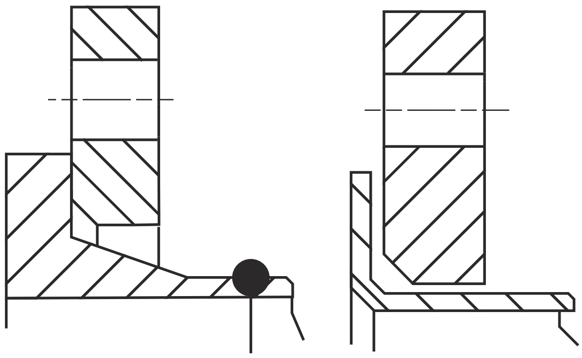


Figure 1.5.3 Loose flange arrangements

5.5.2 Loose flange designs where the pipe end is flared as shown in *Figure 1.5.3 Loose flange arrangements* are only to be used for water pipes and on open ended lines.

5.6 Socket weld joints

5.6.1 Socket weld joints may be used in Class III systems with carbon steel pipes of any outside diameter. Socket weld fittings are to be of forged steel and the material is to be compatible with the associated piping. In particular cases, socket weld joints may be permitted for piping systems of Class I and II having outside diameter not exceeding 88,9 mm. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where toxic or asphyxiating media are conveyed, other than for carbon dioxide fire-extinguishing distribution piping.

5.6.2 The thickness of the socket weld fittings is to meet the requirements of *Vol 2, Pt 7, Ch 1, 6.1 Wrought steel pipes and bends 6.1.3*, but is to be not less than 1,25 times the nominal thickness of the pipe or tube. The diametrical clearance between the outside diameter of the pipe and the bore of the fitting is not to exceed 0,8 mm, and a gap of approximately 1,5 mm is to be provided between the end of the pipe and the bottom of the socket.

5.6.3 The leg lengths of the fillet weld connecting the pipe to the socket weld fitting are to be such that the throat dimension of the weld is not less than the nominal thickness of the pipe or tube.

5.6.4 Socket weld joints may be used in carbon dioxide fire-extinguishing system distribution piping only as permitted by *Vol 2, Pt 7, Ch 1, 5.11 Carbon dioxide (CO2) fire-extinguishing system piping*.

5.7 Threaded sleeve joints

5.7.1 Threaded sleeve joints, in accordance with national or other established standards, may be used with carbon steel pipes within the limits given in *Table 1.5.2 Limiting design conditions for threaded sleeve joints*. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where flammable or toxic media is conveyed.

Table 1.5.2 Limiting design conditions for threaded sleeve joints

Thread type	Outside pipe diameter, in mm		
	Class 1	Class II	Class III

Tapered thread	<33,7	<60,3	<60,3
Parallel thread	—	—	<60,3

5.8 Welded sleeve joints

5.8.1 Welded sleeve joints may be used in Class III systems with carbon steel pipes of any outside diameter. In particular cases, welded sleeve joints may be permitted for piping systems of Class I and II having outside diameter not exceeding 88,9 mm. Such joints are not to be used where fatigue, severe erosion or crevice corrosion is expected to occur or where toxic media are conveyed.

5.8.2 Welded sleeve joints are not to be used in the following locations:

- Bilge pipes in way of deep tanks.
- Cargo oil piping outside of the cargo area for bow or stern loading/discharge.
- Air and sounding pipes passing through cargo tanks.

5.8.3 Welded sleeve joints may be used in piping systems for the storage, distribution and utilisation of fuel oil, lubricating or other flammable oil systems in machinery spaces provided they are located in readily visible and accessible positions. *see also Vol 2, Pt 7, Ch 3, 2.8 Temperature indication 2.8.2*.

5.8.4 Welded sleeve joints are not to be used at deck/bulkhead penetrations that require continuous pipe lengths.

5.8.5 The thickness of the sleeve is to satisfy the requirements of *Vol 2, Pt 7, Ch 1, 6.1 Wrought steel pipes and bends 6.1.3* and *Table 1.6.4 Minimum thickness for steel pipes* but is to be not less than 1,42 times the nominal thickness of the pipe in order to satisfy the throat thickness requirement in *Vol 2, Pt 7, Ch 1, 5.8 Welded sleeve joints 5.8.6*. The radial clearance between the outside diameter of the pipe and the internal diameter of the sleeve is not to exceed 1 mm for pipes up to a nominal diameter of 50 mm, 2 mm on diameters up to 200 mm nominal size and 3 mm for larger size pipes. The pipe ends are to be separated by a clearance of approximately 2 mm at the centre of the sleeve.

5.8.6 The sleeve material is to be compatible with the associated piping and the leg lengths of the fillet weld connecting the pipe to the sleeve are to be such that the throat dimension of the weld is not less than the nominal thickness of the pipe or tube.

5.8.7 The minimum length of the sleeve is to conform to the following formula:

$$L_{si} = 0{,}14D + 36 \text{ mm}$$

where

L_{si} = is the length of the sleeve

D = is defined in *Vol 2, Pt 7, Ch 1, 3.2 Design symbols 3.2.1*.

5.9 Screwed fittings

5.9.1 Screwed fittings, including compression fittings, of an approved type may be used in piping systems for pipes not exceeding 51 mm outside diameter. Where the fittings are not in accordance with an acceptable standard then LR may require the fittings to be subjected to special tests to demonstrate their suitability for the intended service and working conditions.

5.10 Mechanical connections for piping

5.10.1 Pipe unions, compression couplings, or slip-on joints, as shown in *Figure 1.5.4 Examples of mechanical joints A*, may be used if Type Approved for the service conditions and the intended application. The Type Approval is to be based on the results of testing of the actual joints. The acceptable use for each service is indicated in *Vol 2, Pt 7, Ch 1, 5.10 Mechanical connections for piping 5.10.1*and dependence upon the Class of piping, with limiting pipe dimensions, working pressure and temperature is indicated in *Table 1.5.4 Application of mechanical joints depending on class of piping*.

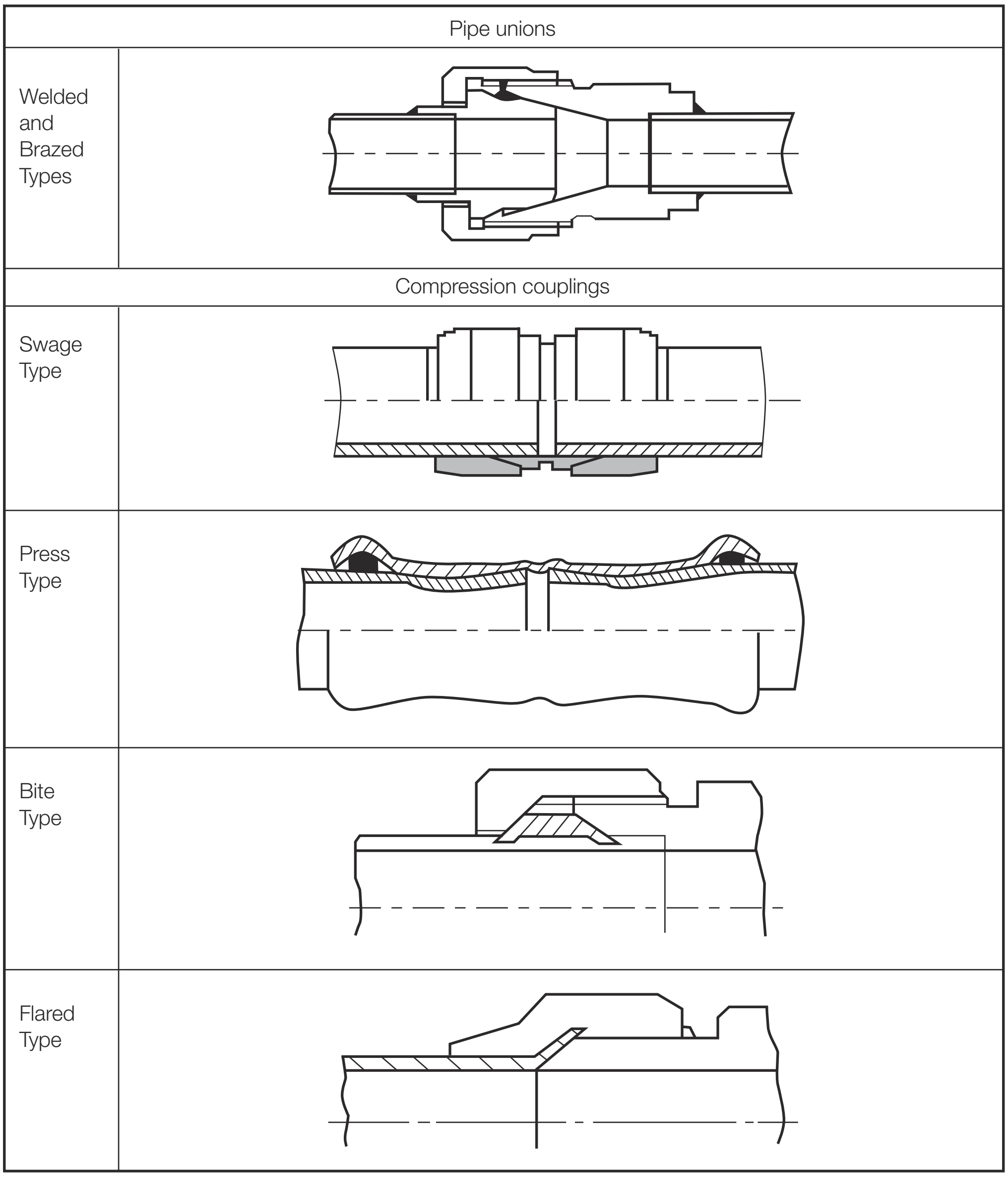


Figure 1.5.4 Examples of mechanical joints A

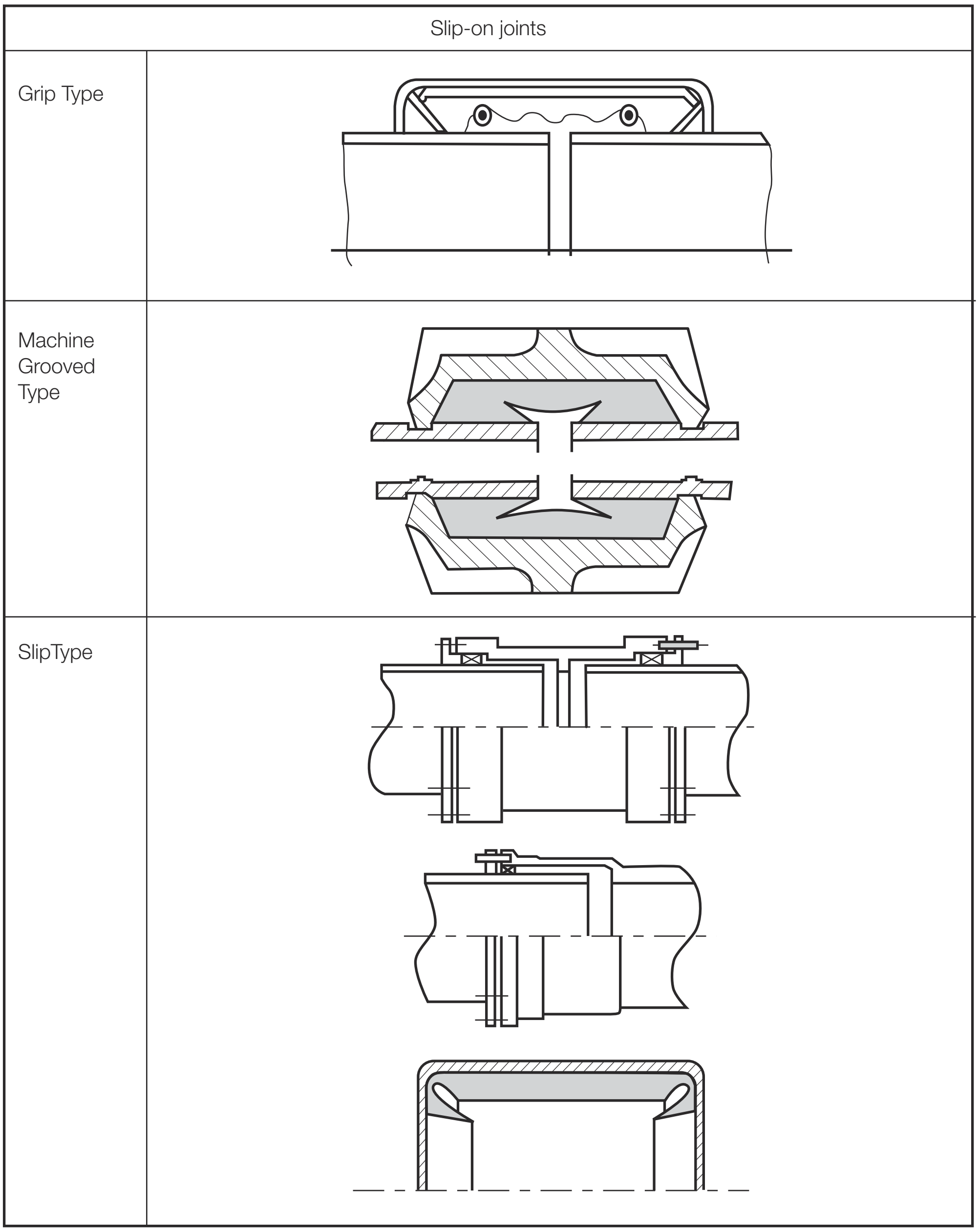


Figure 1.5.5 Examples of mechanical joints B

Table 1.5.3 Application of mechanical joints

Systems	Kind of connections		
	Pipe unions	Compression Coupling (6)	Slip-on joints
Flammable fluids (Flash point <60° C)			
Aircraft and vehicle fuel oil lines	+	+	+5
Vent lines	+	+	+3
Flammable fluids (Flash point > 60° C)			

Aircraft and vehicle fuel oil lines	+	+	+
Ship's machinery fuel oil line	+	+	+2,3
Lubricating oil lines	+	+	+2,3
Hydraulic oil	+	+	+2,3
Thermal oil	+	+	+2,3
Sea water			
Bilge lines	+	+	+1
HP sea-water and water spray	+	+	+3
Foam system	+	+	+3
Sprinkler system	+	+	+3
Ballast system	+	+	+1
Cooling water system	+	+	+1
Tank cleaning services	+	+	+
Non-essential systems	+	+	+
Fresh water			
Cooling water system	+	+	+1
Chilled water systems	+	+	+1
Condensate return	+	+	+1
Made water and demineralised water system	+	+	+
Ancillary system	+	+	+
Sanitary/Drains/Scuppers			
Deck drains (internal)	+	+	+4
Sanitary drains	+	+	+
Scuppers and discharge (overboard)	+	+	-
Sounding /Vent			
Water tanks/Dry spaces	+	+	+
Oil tanks (f.p.>60° C)	+	+	+2,3
Intakes and uptakes (8)			
HVAC trunking (8)			
Miscellaneous			
High pressure (HP) air systems (1)	+	+	–
Medium pressure (MP) air systems (Starting air) (1)	+	+	–
Low pressure (LP) air systems (incl. Control air) (1)	+	+	–
Brine	+	+	+

CO_2 system	+	+	–
Nitrogen system	+	+	–
Steam	+		+7
Key			
+	Application is allowed		
–	Application is not allowed		
Note 1. Inside machinery spaces of category A – only approved fire resistant types.			
Note 2. Not inside machinery spaces of category A or accommodation spaces. May be accepted in other machinery spaces provided the joints are located in easily visible and accessible positions.			
Note 3. Approved fire resistant types. Fire resistant type is a type of connection which, when installed in the system and in the event of failure caused by fire, the failure would not result in fire spread, flooding or the loss of a Mobility or Ship Type system.			
Note 4. Above freeboard deck only.			
Note 5. In pump rooms and open decks – only approved fire resistant types.			
Note 6. If compression couplings include any components which are sensitive to heat, they are to be of approved fire resistant type as required for slip-on joints.			
Note 7. *See Vol 2, Pt 7, Ch 1, 5.10 Mechanical connections for piping 5.10.12*.			
Note 8. Requirements for HVAC trunking or gas turbine updates and intakes are addressed in the relevant Sections of the Rules.			

Table 1.5.4 Application of mechanical joints depending on class of piping

Types of joints	Classes of piping systems		
	Class I	Class II	Class III
Pipe unions Welded and brazed type	+(OD <60,3 mm)	+(OD <60,3 mm)	+
Compression couplings Swage type	–	–	+
Compression couplings Bite type	+(OD <60,3 mm)	+(OD <60,3 mm)	+
Compression couplings Flared type	+(OD <60,3 mm)	+(OD <60,3 mm)	+
Compression couplings Press type	-	-	+
Slip-on joints Machine grooved type	+	+	+
Slip-on joints Grip type	-	+	+
Slip-on joints Slip type	-	+	+
KEY + Application is allowed – Application is not allowed			

5.10.2 Where the application of mechanical joints results in a reduction of pipe wall thickness due to the use of bite type rings or other structural elements, this is to be taken into account in determining the minimum wall thickness of the pipe to withstand the design pressure.

5.10.3 The construction of mechanical joints is to prevent the possibility of tightness failure affected by pressure pulsation, piping vibration, temperature variation and other similar adverse effects during operation on board.

5.10.4 The materials used in the construction of mechanical joints are to be compatible with the piping material and internal/ external media.

5.10.5 Mechanical joints for pressure pipes are to be tested to a burst pressure of 4 times the design pressure. For design pressures above 200 bar the required burst pressure will be specially considered.

5.10.6 In general, mechanical joints are to be of fire resistant type where required by *Vol 2, Pt 7, Ch 1, 5.10 Mechanical connections for piping 5.10.1*.

5.10.7 Mechanical pipe connections having sealing components sensitive to heat are not to be used in spaces where leakage or failure caused by fire could result in fire spread, flooding or loss of a Mobility or Ship Type system.

5.10.8 Mechanical joints, which in the event of damage could cause fire or flooding, are not to be used in piping sections directly connected to the sea openings or tanks containing flammable fluids.

5.10.9 The mechanical joints are to be designed to withstand internal and external pressure as applicable and where used in suction lines are to be capable of operating under vacuum.

5.10.10 Generally, slip-on joints are not to be used in pipelines in cargo holds, tanks, and other spaces which are not easily accessible. Application of these joints inside tanks may only be accepted where the medium conveyed is the same as that in the tanks.

5.10.11 Unrestrained slip-on joints are only to be used in cases where compensation of lateral pipe deformation is necessary. Usage of these joints as the main means of pipe connection is not permitted.

5.10.12 Restrained slip-on joints are permitted in steam pipes with a design pressure of 10 bar or less on the weather decks of oil and chemical tankers to accommodate axial pipe movement, *see Vol 2, Pt 7, Ch 2, 2.7 Provision for expansion*.

5.10.13 Mechanical joints are to be tested in accordance with the test requirements in LR Test Specification Number 2. The programme of testing is to be agreed with LR and is to include the following tests as relevant to the service conditions and the intended application:

- leakage test;
- vacuum test;
- vibration (fatigue) test;
- fire endurance test;
- burst pressure test;
- pressure pulsation test;
- reassembly test;
- pull-out test;
- static displacement/misalignment test.

5.11 Carbon dioxide (CO2) fire-extinguishing system piping

5.11.1 The piping for carbon dioxide fire-extinguishing systems is to comply with the requirements of *Chapter 5 - Fixed Gas Fire-Extinguishing Systems* of the FSS Code, as applicable. For purposes of classification, any use of the word ‘Administration’ in the FSS Code is to be taken to mean LR.

5.11.2 Materials for the distribution manifolds between the carbon dioxide storage bottles and the discharge valves to each section and associated pipes, valves and fittings of high pressure systems are to be manufactured and tested in accordance with the requirements for Class I piping systems. Pipes are to meet the minimum wall thickness requirements of *Table 1.6.4 Minimum thickness for steel pipes* and the manifold system is to be hydraulically tested to a pressure of 190 bar. A high pressure system is defined as a system where the carbon dioxide is stored at ambient temperature. Materials for the distribution manifolds between the carbon dioxide storage vessel(s) and the discharge valves to each section and associated pipes, valves and fittings of low pressure systems are to be manufactured and tested in accordance with the requirements for Class II piping systems and the manifold system is to be hydraulically tested to a pressure of 33 bar. A low pressure system is defined as a system where the carbon dioxide is stored at a working pressure in the range of 1,8 N/mm^2 to 2,2 N/mm^2.

5.11.3 Piping downstream of the distribution valve(s) for high pressure systems is to be manufactured and tested in accordance with the requirements for Class II piping and is to meet the minimum wall thickness requirements of *Table 1.6.4 Minimum thickness for steel pipes*. After installation the distribution system is to be leak tested at a pressure of 6 bar. Piping downstream of the distribution valve(s) for low pressure systems is to be manufactured and tested in accordance with the requirements for Class III piping. After installation the distribution system is to be leak tested at a pressure of 6 bar. Class III piping

may be used for open-ended distribution piping downstream of the distribution valve(s) of high pressure systems where agreed by LR and where meeting the minimum wall thickness requirements of Table 1.6.4 and where a minimum of ten per cent of the piping is hydraulically tested at a pressure of 125 bar. This testing is to be carried out before installation.

5.11.4 Any part of the carbon dioxide fire-extinguishing system piping is to be of galvanised steel or of corrosion-resistant steel. Where full penetration butt welding is used, the pipe is to be protected against corrosion in the area of the weld seam after welding. The process for protecting the pipe internally against corrosion is to be of an approved type. All pipes are to be arranged to be self-draining. Where pipes are to be led into refrigerated spaces, this is subject to special consideration. The ends of distribution pipes downstream of the distribution valve(s) are to extend at least 50 mm beyond the last nozzle and are to be fitted with a dirt trap consisting of an open-ended tee with a capped nipple.

5.11.5 If it is necessary for carbon dioxide pipes to pass through accommodation spaces, the pipe is to be seamless and is to meet the requirements for Class II pipes. Joints are to be made only by welding and the pipes are to be hydraulically tested after installation at a pressure of 50 bar.

5.11.6 The following means are permitted for making joints on carbon dioxide fire-extinguishing system piping;

(a) Full penetration butt welding, where the pipe is galvanised, *see Vol 2, Pt 7, Ch 1, 5.11 Carbon dioxide (CO2) fire-extinguishing system piping 5.11.4*.
(b) Couplings as permitted by *Vol 2, Pt 7, Ch 1, 5.10 Mechanical connections for piping 5.10.1*.
(c) Cone connections.
(d) Tapered screw joints, where allowed by *Vol 2, Pt 7, Ch 1, 5.11 Carbon dioxide (CO2) fire-extinguishing system piping 5.11.9* and where meeting the requirements of *Vol 2, Pt 7, Ch 1, 5.11 Carbon dioxide (CO2) fire-extinguishing system piping 5.11.9*.
(e) Flanged joints.
(f) Socket weld joints to acceptable National Standards and where allowed by *Vol 2, Pt 7, Ch 1, 5.11 Carbon dioxide (CO2) fire-extinguishing system piping 5.11.7* and where meeting the requirements of *Vol 2, Pt 7, Ch 1, 5.11 Carbon dioxide (CO2) fire-extinguishing system piping 5.11.8*.

5.11.7 Socket weld joints of an approved type may be used downstream of the distribution valve(s), provided that the requirements for materials and limitations on outside diameter applicable for Class II piping are applied.

5.11.8 Where socket weld joints are utilised, the pipes in the way of the weld joints are to be adequately supported and the joints are to be located where they are visible. Where welding is to be carried out in situ, the piping is to be kept clear of adjacent structures to allow sufficient access for preheating and welding, which is to be carried out in accordance with approved procedures.

5.11.9 Threaded joints are only allowed inside protected spaces and in carbon dioxide bottles storage rooms. They should have no exposed screw threads and any thread sealing medium should be selected as to ensure no protrusions or debris might be produced into the pipe.

■ *Section 6*
Carbon and low alloy steel piping and components

6.1 Wrought steel pipes and bends

6.1.1 The maximum permissible design stress, σ, is to be taken as the lowest of the following values:

$$\sigma = \frac{E_t}{1,6} \quad \sigma = \frac{R_{20}}{2,7} \quad \sigma = \frac{S_R}{1,6}$$

where

E_t = specified minimum lower yield or 0,2 per cent proof stress at the design temperature. In the case of stainless steel, the 1,0 per cent proof stress at design temperature is to be used

R_{20} = specified minimum tensile strength at ambient temperature

S_R = average stress to produce rupture in 100 000 hours at the design temperature

Values of the maximum permissible design stress, σ, obtained from the properties of the steels specified in *Ch 6 Steel Pipes and Tubes* of the Rules for Materials are shown in *Table 1.6.1 Carbon and carbon-manganese steel pipes* and *Table 1.6.2 Alloy steel pipes*. For intermediate values of specified minimum strengths and temperatures, values of the permissible design stress may be obtained by interpolation.

6.1.2 Where it is proposed to use, for high temperature service, alloy steels other than those detailed in *Table 1.6.2 Alloy steel pipes* particulars of the tube sizes, design conditions and appropriate national or proprietary material specifications are to be submitted for consideration.

Table 1.6.1 Carbon and carbon-manganese steel pipes

Specified minimum tensile strength, N/mm^2	Maximum permissible stress, N/mm^2												
	Maximum design temperature, °C												
	50	100	150	200	250	300	350	400	410	420	430	440	450
320	107	105	99	92	78	62	57	55	55	54	54	54	49
360	120	117	110	103	91	76	69	68	68	68	64	56	49
410	136	131	124	117	106	93	86	84	79	71	64	56	49
460	151	146	139	132	122	111	101	99	98	85	73	62	53
490	160	156	148	141	131	121	111	109	98	85	73	62	53

6.1.3 The minimum thickness, *t*, of straight steel pipes is to be determined by the following formula:

$$t = \left(\frac{pD}{20\,\sigma\,e + p} + c \right) \frac{100}{100 - a}\ \text{mm}$$

where *p*, *D*, *e* and *a* are as defined in *Vol 2, Pt 7, Ch 1, 3.2 Design symbols 3.2.1*

c = is obtained from *Table 1.6.3 Values of c for steel pipes*

σ = is defined in *Vol 2, Pt 7, Ch 1, 2.2 Definitions 2.2.1* and obtained from *Table 1.6.1 Carbon and carbon-manganese steel pipes* or *Table 1.6.2 Alloy steel pipes*

For pipes passing through tanks, an additional corrosion allowance is to be added to take account of external corrosion; the addition will depend on the external medium and the value is to be in accordance with *Table 1.6.4 Minimum thickness for steel pipes*. Where the pipes are efficiently protected, the corrosion allowance may be reduced by not more than 50 per cent.

Table 1.6.2 Alloy steel pipes

Type of steel	Specified minimum tensile strength, N/mm^2	Maximum permissible stress, N/mm^2									
		Maximum design temperature, °C									
		50	100	200	300	350	400	440	450	460	470
1 Cr 1$^{1}/_{4}$2 Mo	440	159	150	137	114	106	102	101	101	100	99
2 1$^{1}/_{4}$4 Cr 1 Mo annealed	410	76	67	57	50	47	45	44	43	43	42
2 1$^{1}/_{4}$4 Cr 1 Mo normalised and tempered (Note 1)	490	167	163	153	144	140	136	130	128	127	116
2 1$^{1}/_{4}$4 Cr 1 Mo normalised and tempered (Note 2)	490	167	163	153	144	140	136	130	122	114	105
1$^{1}/_{4}$2 Cr 1$^{1}/_{4}$2 Mo 1$^{1}/_{4}$4 V	460	166	162	147	120	115	111	106	105	103	102
		Maximum design temperature, °C									
		480	490	500	510	520	530	540	550	560	570
1 Cr 1$^{1}/_{4}$2 Mo	440	98	97	91	76	62	51	42	34	27	22
2 1$^{1}/_{4}$4 Cr 1 M annealed	410	42	42	41	41	41	40	40	40	37	32
2 1$^{1}/_{4}$4 Cr 1 Mo normalised and tempered (Note 1)	490	106	96	86	76	67	58	49	43	37	32
2 1$^{1}/_{4}$4 Cr 1 Mo normalised and tempered (Note 2)	490	96	88	79	72	64	56	49	43	37	32
1$^{1}/_{4}$2 Cr 1$^{1}/_{4}$2 Mo 1$^{1}/_{4}$4 V	460	101	99	97	94	82	72	62	53	45	37

Note 1. Maximum permissible stress values applicable when the tempering temperature does not exceed 750°C

Note 2. Maximum permissible stress values applicable when the tempering temperature exceeds 750°C

Table 1.6.3 Values of *c* for steel pipes

Piping service	*c* mm
Superheated steam systems	0,3
Saturated steam systems	0,8
Steam coil systems in cargo tanks	2,0
Feed water for boilers in open circuit systems	1,5
Feed water for boilers in closed circuit systems	0,5
Blow down (for boilers) systems	1,5
Compressed air systems	1,0
Hydraulic oil systems	0,3

Lubricating oil systems	0,3
Fuel oil systems	1,0
Cargo oil systems	2,0
Refrigerating plants	0,3
Fresh water systems	0,8
Sea-water systems in general	3,0

Table 1.6.4 Minimum thickness for steel pipes

External diameter D in mm	Pipes in general in mm	Venting, overflow and sounding pipes for structural tanks in mm	Bilge, ballast and general sea-water pipes in mm	Bilge, air, overflow and sounding pipes through ballast and fuel tanks, ballast lines through fuel tanks and fuel lines through ballast tanks in mm
10,2–12	1,6	–	–	–
13,5–19	1,8	–	–	–
20	2,0	–	–	–
21,3–25	2,0	–	3,2	–
26,9–33,7	2,0	–	3,2	–
38–44,5	2,0	4,5	3,6	6,3
48,3	2,3	4,5	3,6	6,3
51–63,5	2,3	4,5	4,0	6,3
70	2,6	4,5	4,0	6,3
76,1–82,5	2,6	4,5	4,5	6,3
88,9–108	2,9	4,5	4,5	7,1
114,3–127	3,2	4,5	4,5	8,0
133–139,7	3,6	4,5	4,5	8,0
152,4–168,3	4,0	4,5	4,5	8,8
177,8	4,5	5,0	5,0	8,8
193,7	4,5	5,4	5,4	8,8
219,1	4,5	5,9	5,9	8,8
244,5–273	5,0	6,3	6,3	8,8
298,5–368	5,6	6,3	6,3	8,8
406,4–457,2	6,3	6,3	6,3	8,8
Note The pipe diameters and wall thickness given in the table are based on common international standards. Diameter and thickness according to other National or International Standards will be considered.				

6.1.4 The minimum thickness, t_{b}, of a straight steel pipe to be used for a pipe bend is to be determined by the following formula, except where it can be demonstrated that the use of a thickness less than t_{b} would not reduce the thickness below t at any point after bending:

$$t_{\text{b}} = \left[\left(\frac{pD}{20\,\sigma\,e + p}\right)\left(1 + \frac{D}{2,5R}\right) + c\right]\frac{100}{100 - a}\ \text{mm}$$

where p, D, R, e and a are as defined in *Vol 2, Pt 7, Ch 1, 3.2 Design symbols 3.2.1*

σ and c are as defined in *Vol 2, Pt 7, Ch 1, 6.1 Wrought steel pipes and bends 6.1.3*. In general, R is to be not less than 3D.

6.1.5 Where the minimum thickness calculated by *Vol 2, Pt 7, Ch 1, 6.1 Wrought steel pipes and bends 6.1.3* or *Vol 2, Pt 7, Ch 1, 6.1 Wrought steel pipes and bends 6.1.4* is less than that shown in *Table 1.6.4 Minimum thickness for steel pipes*, the minimum nominal thickness for the appropriate standard pipe size shown in the Table is to be used. No allowance is required for

negative tolerance, corrosion or reduction in thickness due to bending on this nominal thickness. For larger diameters, the minimum thickness will be considered. For threaded pipes, where permitted, the minimum thickness is to be measured at the bottom of the thread.

6.1.6 For air, bilge, ballast, fuel, overflow, sounding and venting pipes as listed in *Table 1.6.4 Minimum thickness for steel pipes*, where the pipes are efficiently protected against corrosion, the thickness may be reduced by not more than 1 mm.

6.1.7 The internal diameter for bilge, venting and overflow pipes listed in *Table 1.6.4 Minimum thickness for steel pipes* is to be not less than 50 mm. The internal diameter for sounding pipes is to be not less than 32 mm.

■ *Section 7*
Copper and copper alloy piping and components

7.1 Copper and copper alloy pipes, valves and fittings

7.1.1 Materials for Class I and Class II piping systems, also for ship-side valves and fittings and valves on the collision bulkhead, are to be manufactured and tested in accordance with the requirements of *Ch 9 Copper Alloys* of the Rules for Materials, *see also Vol 2, Pt 7, Ch 1, 4.1 Metallic materials*.

7.1.2 Materials for Class III piping systems are to be manufactured and tested in accordance with the requirements of acceptable national specifications. The manufacturer's test certificate will be acceptable and is to be provided for each consignment of material. *See Ch 1, 3.1 General 3.1.3* of the Rules for Materials.

7.1.3 Pipes are to be seamless, and branches are to be provided by cast or stamped fittings, pipe pressings or other approved fabrications.

7.1.4 Brazing and welding materials are to be suitable for the operating temperature and for the medium being carried. All brazing and welding are to be carried out to the satisfaction of the Surveyors.

7.1.5 In general, the maximum permissible service temperature of copper and copper alloy pipes, valves and fittings is not to exceed 200°C for copper and aluminium brass, and 300°C for copper-nickel. Cast bronze valves and fittings complying with the requirements of *Ch 9 Copper Alloys* of the Rules for Materials may be accepted up to 260°C.

7.1.6 The minimum thickness, t, of straight copper and copper alloy pipes is to be determined by the following formula:

$$t = \left(\frac{pD}{20\,\sigma + p} + c\right)\frac{100}{100 - a}\ \text{mm}$$

where p, D and a are as defined in *Vol 2, Pt 7, Ch 1, 3.2 Design symbols 3.2.1*

c = corrosion allowance
= 0,8 mm for copper, aluminium brass, and copper-nickel alloys where the nickel content is less than 10 per cent
= 0,5 mm for copper-nickel alloys where the nickel content is 10 per cent or greater
= 0 where the media are non-corrosive relative to the pipe material

σ = maximum permissible design stress, in N/mm^2, from *Table 1.7.1 Copper and copper alloy pipes*. Intermediate values of stresses may be obtained by linear interpolation.

Table 1.7.1 Copper and copper alloy pipes

Pipe material	Condition of supply	Specified minimum tensile strength, N/mm^2	Permissible stress, N/mm^2										
			Maximum design temperature, °C										
			50	75	100	125	150	175	200	225	250	275	300
Copper	Annealed	220	41,2	41,2	40,2	40,2	34,3	27,5	18,6	–	–	–	–

Aluminium brass	Annealed	320	78,5	78,5	78,5	78,5	78,5	51,0	24,5	–	–	–	–
90/10 Copper-nickel-iron	Annealed	270	68,6	68,6	67,7	65,7	63,7	61,8	58,8	55,9	52,0	48,1	44,1
70/30 Copper-nickel	Annealed	360	81,4	79,4	77,5	75,5	73,5	71,6	69,6	67,7	65,7	63,7	61,8

7.1.7 The minimum thickness, t_b of a straight seamless copper or copper alloy pipe to be used for a pipe bend is to be determined by the formula below, except where it can be demonstrated that the use of a thickness less than t_b would not reduce the thickness below t at any point after bending

$$t_b = \left[\left(\frac{pD}{20\,\sigma + p}\right)\left(1 + \frac{D}{2,5R}\right) + c\right]\frac{100}{100 - a}\ \text{mm}$$

where *p*, *D*, *R* and a are as defined in *Vol 2, Pt 7, Ch 1, 3.2 Design symbols 3.2.1*

σ and *c* are as defined in *Vol 2, Pt 7, Ch 1, 7.1 Copper and copper alloy pipes, valves and fittings 7.1.6*. In general, *R* is to be not less than 3*D*.

7.1.8 Where the minimum thickness calculated by *Vol 2, Pt 7, Ch 1, 7.1 Copper and copper alloy pipes, valves and fittings 7.1.6* or *Vol 2, Pt 7, Ch 1, 7.1 Copper and copper alloy pipes, valves and fittings 7.1.7* is less than shown in *Table 1.7.2 Minimum thickness for copper and copper alloy pipes*, the minimum nominal thickness for the approriate standard pipe size shown in the Table is to be used. No allowance is required for negative tolerance or reduction in thickness due to bending on this nominal thickness. For threaded pipes, where permitted, the minimum thickness is to be measured at the bottom of the thread.

Table 1.7.2 Minimum thickness for copper and copper alloy pipes

Standard pipe sizes (outside diameters)	Minimum overriding nominal thickness	
	Copper	Copper alloy

mm		mm	mm	mm
8	to	10	1,0	0,8
12	to	20	1,2	1,0
		44,5	1,5	1,2
25	to	76,1	2,0	1,5
50	to	108	2,5	2,0
88,9	to	159	3,0	2,5
133	to	267	3,5	3,0
193,7	to	457,2	4,0	3,5
273	to	508	4,5	4,0

7.2 Heat treatment

7.2.1 Pipes which have been hardened by cold bending are to be suitably heat treated on completion of fabrication and prior to being tested by hydraulic pressure. Copper pipes are to be annealed and copper alloy pipes are to be either annealed or stress relief heat treated

■ *Section 8*
Cast iron piping and components

8.1 Spheroidal or nodular graphite cast iron

8.1.1 Spheroidal or nodular graphite iron may be accepted for bilge, ballast and cargo oil piping.

8.1.2 Spheroidal or nodular graphite iron castings for pipes, valves and fittings in Class II and Class III piping systems are to be made in a grade having a specified minimum elongation not less than 12 per cent on a gauge length of where $5,65\sqrt{S_0}$ is the actual cross-sectional area of the test piece.

8.1.3 Castings for Class II systems, also for ship-side valves and fittings and valves on the collision bulkhead, are to be manufactured and tested in accordance with the requirements of *Ch 7 Iron Castings* of the Rules for Materials. Castings for Class III systems are to comply with the requirements of acceptable national specifications. A manufacturer's test certificate will be accepted and is to be provided for each consignment of material for Class III systems, *see also* 1.6 and *Ch 1, 3.1 General 3.1.3* of the Rules for Materials.

8.1.4 Proposals for the use of this material in Class I piping systems will be specially considered, but in no case is the material to be used in systems where the design temperature exceeds 350°C.

8.1.5 Where the elongation is less than the minimum required by *Vol 2, Pt 7, Ch 1, 8.1 Spheroidal or nodular graphite cast iron 8.1.2*, the material is, in general, to be subject to the same limitations as grey cast iron.

8.2 Grey cast iron

8.2.1 Grey cast iron pipes, valves and fittings will, in general, be accepted in Class III piping systems except as stated in *Vol 2, Pt 7, Ch 1, 8.2 Grey cast iron 8.2.3*.

8.2.2 Grey cast iron is not to be used for pipes, valves and other fittings handling media having temperatures above 220°C or for piping subject to pressure shock, excessive strains or vibrations.

8.2.3 Grey cast iron is not to be used for the following:

- Pipes for steam systems and fire extinguishing systems.
- Pipes, valves and fittings for boiler blow-down systems and other piping systems subject to shock or vibration.
- Ship-side valves and fittings, *see Vol 2, Pt 7, Ch 2, 2.5 Ship-side valves and fittings (other than those on scuppers and sanitary discharges)*.
- Valves fitted on the collision bulkhead, *see Vol 2, Pt 7, Ch 2, 3.3 Fore and after peaks*.
- Bilge lines in tanks.
- Pipes and fittings in flammable oil systems where the design pressure exceeds 7 bar or the design operating temperature is greater than 60°C.
- Valves fitted to tanks containing flammable oil under static pressure.
- Valve chests and fittings for starting air systems, *see Vol 2, Pt 2, Ch 1, 8.3 Starting air pipe systems and safety fittings 8.3.4*.

8.2.4 Castings for Class III piping systems are to comply with acceptable national specifications.

■ *Section 9*
Stainless steel piping and components

9.1 General

9.1.1 Stainless steels may be used for a wide range of services and are particularly suitable for use at elevated temperatures. For guidance on the use of Austenitic steels in sea water systems, *see Vol 2, Pt 7, Ch 1, 17.3 Steel pipes 17.3.4*.

9.1.2 The minimum thickness of stainless steel pipes is to be determined from the formula given in *Vol 2, Pt 7, Ch 1, 6.1 Wrought steel pipes and bends 6.1.3* or *Vol 2, Pt 7, Ch 1, 6.1 Wrought steel pipes and bends 6.1.4* using a corrosion allowance of 0,8 mm. Values of the 1,0 per cent proof stress and tensile strength of the material for use in the formula in *Vol 2, Pt 7, Ch 1, 6.1 Wrought steel pipes and bends 6.1.1* may be obtained from *Table 6.5.2 Mechanical properties for acceptance purposes*of the Rules for Materials.

9.1.3 Where stainless steel is used in lubricating oil and hydraulic oil systems, the corrosion allowance may be reduced to 0 mm. For pipes passing through tanks, an additional corrosion allowance is to be added to take account of external corrosion; the addition will depend on the external medium and the value is to be in accordance with *Table 1.6.3 Values of c for steel pipes* .

9.1.4 In no case is the thickness of stainless steel pipes to be less than that shown in *Table 1.9.1 Minimum thickness for stainless steel pipes*.

Table 1.9.1 Minimum thickness for stainless steel pipes

Standard pipe sizes, (outside diameter), in mm			Min.nominal thickness in mm
8,0	to	10,0	0,8
10,2	to	17,2	1,0

21,3	to	48,3	1,6
60,3	to	88,9	2,0
114,3	to	168,3	2,3
219,1			2,6
273,0			2,9
323,9	to	406,4	3,6
over	406,4		4,0

Note Diameters and thicknesses according to national or international standards may be accepted.

9.1.5 Joints in stainless steel pipework may be made by any of the techniques described in *Vol 2, Pt 7, Ch 1, 5.2 Flange connections* to *Vol 2, Pt 7, Ch 1, 5.8 Welded sleeve joints*.

9.1.6 Where pipework is butt welded, this should preferably be accomplished without the use of backing rings, in order to eliminate the possibility of crevice corrosion between the backing ring and pipe.

■ *Section 10*
Aluminium piping and components

10.1 General

10.1.1 The use of aluminium alloy material in Class III piping systems will be considered in relation to the fluid being conveyed and operating conditions of temperature and pressure.

10.1.2 In general, aluminium alloy may be used for air and sounding pipes for water tanks and dry spaces providing it can be shown that pipe failure will not cause a loss of integrity across watertight divisions. In ships of aluminium construction, aluminium alloy may also be used for air and sounding pipes for fuel oil, lubricating oil and other flammable liquid tanks provided the pipes are suitably protected against the effects of fire.

10.1.3 Aluminium alloy pipes are not to be used in machinery spaces or cargo holds for conveying fuel oil, lubricating oil or other flammable liquids, or for bilge suction pipework within machinery spaces.

10.1.4 Aluminium alloy pipes are not acceptable for fire extinguishing pipes unless they are suitably protected against the effect of heat.

10.1.5 The minimum thickness of aluminium alloy pipes is to be not less than that shown in *Table 1.10.1 Minimum thickness of aluminium pipes*.

Table 1.10.1 Minimum thickness of aluminium pipes

Nominal pipe size (mm)	Minimum wall thickness (mm)
10	1,7
15	2,1
20	2,1
25	2,8
40	2,8
50	2,8
80	3,0
100	3,0

150	3,4
200	3,8
250 and over	4,2

10.1.6 Design requirements for aluminium pressure pipes for design pressures greater than 7 bar will be specially considered.

10.1.7 Attention is drawn to the susceptibility of aluminium to corrosion in the region of welded connections.

■ *Section 11* Pipe connections

11.1 General

11.1.1 Proposals to use plastics pipes in shipboard piping systems will be considered in relation to the properties of the materials, the operating conditions, the intended service and location. Details are to be submitted for approval. Special consideration will be given to any proposed service for plastics pipes not mentioned in these Rules.

11.1.2 Attention is also to be given to the *Guidelines for the Application of Plastic Pipes on Ships* contained in IMO Resolution A.753(18).

11.1.3 Plastics pipes and fittings will, in general, be accepted in Class III piping systems. Proposals for the use of plastics in Class I and Class II piping systems will be specially considered.

11.1.4 For Class I, Class II and any Class III piping systems for which there are Rule requirements, the pipes are to be of a type which has been approved by LR.

11.1.5 For domestic and similar services where there are no Rule requirements, the pipes need not be of a type which has been approved by LR. However, the fire safety aspects as referenced in *Vol 2, Pt 7, Ch 1, 11.4 Fire performance criteria*, are to be considered.

11.1.6 The use of plastics piping and components for magazine piping systems or for piping systems that may pass through magazine spaces is not permitted.

11.1.7 The use of plastics pipes may be restricted, as specified by the Naval Administration.

11.1.8 Where there is a restriction on the use of plastics materials for piping systems and associated equipment installed in naval ships, the Naval Administration may allow their use following a Risk Assessment, in accordance with *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)* that addresses the following:

(a) the potential fire risks in the space containing the plastics materials;
(b) The effect of a fire in the compartment containing plastics materials in terms of fire spread and of producing excessive quantities of smoke and toxic products.
(c) An engineering justification for the use of plastics materials in preference to metallic materials which are not sensitive to heat.

11.2 Design and performance criteria

11.2.1 Pipes and fittings are to be of robust construction and are to comply with a National or other established Standard, consistent with the intended use. Particulars of pipes, fittings and joints are to be submitted for consideration.

11.2.2 The design and performance criteria of all piping systems, independent of service or location, are to meet the requirements of *Vol 2, Pt 7, Ch 1, 11.3 Design strength*.

11.2.3 Depending on the service and location, the fire safety aspects relating to the use of plastics materials for pipes are to satisfy the requirements of *Vol 2, Pt 7, Ch 1, 11.4 Fire performance criteria*. *See also Vol 2, Pt 7, Ch 1, 11.1 General 11.1.8*

11.2.4 Plastics piping, connections and fittings to be electrically conductive when:

(a) carrying fluids capable of generating electrostatic charges;
(b) passing through hazardous zones and spaces, regardless of the fluid being conveyed.

Suitable precautions against the build up of electrostatic charges are to be provided in accordance with the requirements of *Vol 2, Pt 7, Ch 1, 11.5 Electrical conductivity*, *see also Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding* .

11.3 Design strength

11.3.1 The strength of pipes is to be determined by hydrostatic pressure tests to failure on representative sizes of pipe. The strength of fittings is to be not less than the strength of the pipes.

11.3.2 The nominal internal pressure, pN_i, of the pipe is to be determined by the lesser of the following:

$$pN_i \leq \frac{p_{st}}{4}$$

$$pN_i \leq \frac{p_{lt}}{2,5}$$

where

p_{st} = short term hydrostatic test failure pressure, in bar

p_{lt} = long term hydrostatic test failure pressure (100 000 hours), in bar

Testing may be carried out over a reduced period of time using suitable standards, such as ASTM D2837 and D1598.

11.3.3 The nominal external pressure, pN_e, of the pipe, defined as the maximum total of internal vacuum and external static pressure head to which the pipe may be subjected, is to be determined by the following:

$$pN_e \leq \frac{p_{col}}{3}$$

where

p_{col} = pipe collapse pressure, in bar

= The pipe collapse pressure is not to be less than 3 bar.

11.3.4 Piping is to meet these design requirements over the range of service temperature it will experience.

11.3.5 High temperature limits and pressure reductions relative to nominal pressures are to be according to a recognised standard, but in each case the maximum working temperature is to be at least 20°C lower than the minimum temperature of deflection under load of the resin or plastics material without reinforcement. The minimum heat distortion temperature is not to be less than 80°C. *See also Ch 14, 4 Plastics pipes and fittings* of the Rules for Materials.

11.3.6 Where it is proposed to use plastics piping in low temperature services, design strength testing is to be made at a temperature 10°C lower than the minimum working temperature.

11.3.7 For guidance, typical temperature and pressure limits are indicated in *Table 1.11.1 Typical temperature and pressure limits for thermoplastic pipes* and *Table 1.11.2 Typical temperature and pressure limits for glassfibre reinforced epoxy (GRE) and polyester (GRP) pipes*. The Tables are related to water service only. Transport of chemicals or other media are to be considered on a case by case basis.

Table 1.11.1 Typical temperature and pressure limits for thermoplastic pipes

Material	Nominal pressure, bar	Maximum permissible working pressure, bar		
		–20 to 0°C	30°C	40°C
HDPE	10	7,5	6	
	16	12	9,5	6
HDPE High density polyethylene				

Table 1.11.2 Typical temperature and pressure limits for glassfibre reinforced epoxy (GRE) and polyester (GRP) pipes

Minimum heat distortion temperature of resin	Nominal pressure, bar	Maximum permissible working pressure, bar							
		–50 to 30°C	40°C	50°C	60°C	70°C	80°C	90°C	95°C
80°C	10	10	9	7,5	6				
	16	16	14	12	9,5				
	25	16	16	16	15				
100°C	10	10	10	9,5	8,5	7	6		
	16	16	16	15	13,5	11	9,5		
	25	16	16	16	16	16	15		
135°C	10	10	10	10	10	9,5	8,5	7	6
	16	16	16	16	16	15	13,5	11	9,5
	25	16	16	16	16	16	16	16	15

11.3.8 The selection of plastics materials for piping is to take account of other factors such as impact resistance, ageing, fatigue, erosion resistance, fluid absorption and material compatibility such that the design strength of the piping is not reduced below that required by these Rules.

11.3.9 Design strength values may be verified experimentally or by a combination of testing and calculation methods.

11.4 Fire performance criteria

11.4.1 Where plastics pipes are used in systems essential to the safe operation of the ship, or for containing combustible liquids or sea-water where leakage or failure could result in fire or in the flooding of watertight compartments, the pipes and fittings, including couplings with flexible internal seals, are to be of a type which has been fire endurance tested in accordance with the requirements of *Table 1.11.3 Fire endurance requirements* .

Table 1.11.3 Fire endurance requirements

Piping systems	Location									
	A Machinery spaces of Category A	B Other Machinery spaces	C Special category spaces	D Other dry compartments	E Refuelling tanks (f.p. ≤ 60°C)	F Fuel oil tanks	G Ballast water tanks	H Cofferdams void spaces pipe tunnel and ducts	I Accommodation service and control spaces	J Open decks
FLAMMABLE LIQUIDS (f.p. ≤ 60°C)										
1 Refuelling lines	N/A	N/A	N/A	N/A	0	N/A	0	0	N/A	L1[2]
FLAMMABLE LIQUIDS (f.p. > 60°C)										
2 Refuelling lines	X	X	X	X	N/A[3]	0	0[10]	0	N/A	L1
3 Fuel oil	X	X	X	X	N/A[3]	0	0	0	L1	L1
4 Lubricating oil	X	X	X	X	N/A	N/A	N/A	0	L1	L1
5 Hydraulic oil	X	X	X	X	0	0	0	0	L1	L1
SEAWATER[1]										
6 Bilge main and branches	X	X	X	X	N/A	0	0	0	N/A	L1
7 Fire main and water spray	L1	L1	X	N/A	N/A	N/A	0	0	X	L1
8 Foam system	L1	L1	N/A	N/A	N/A	N/A	N/A	0	L1	L1
9 Sprinkler system	L1	L1	X	N/A	N/A	N/A	0	0	L3	L3
10 Ballast	L3	L3	L3	X	0[10]	0	0	0	L2	L2
11 Cooling water, Mobility and/or Ship Type systems	L3	L3	N/A	N/A	N/A	N/A	0	0	N/A	L2
12 Non-essential systems	0	0	0	0	N/A	0	0	0	0	0
FRESHWATER										
13 Cooling water, Mobility and/or Ship Type systems	L3	L3	N/A	N/A	N/A	0	0	0	L3	L3
14 Condensate return	L3	L3	0	0	N/A	N/A	N/A	0	0	0

15 Non-essential systems	0	0	0	0	N/A	0	0	0	0	0
SANITARY/ DRAINS/ SCUPPERS										
16 Deck drains (internal)	L1[4]	L1[4]	L1[4]	0	N/A	0	0	0	0	0
17 Sanitary drains (internal)	0	0	0	0	N/A	0	0	0	0	0
18 Scuppers and discharges (overboard)	0[1,6]	0[1,6]	0[1,6]	0[1,6]	0	0	0	0	0[1,6]	0
SOUNDING/AIR										
19 Water tanks/dry spaces	0	0	0	0	0	0	0	0	0	0[8]
20 Oil tanks (f.p. > 60°C)	X	X	X	X	X[3]	0	0	0	X	X
MISCELLANEOUS										
21 Control air	L1[5]	L1[5]	L1[5]	L1[5]	N/A	0	0	0	L1[5]	L1[5]
22 Service air (Ancillary)	0	0	0	0	N/A	0	0	0	0	0
23 Brine	0	0	0	0	N/A	N/A	N/A	0	0	0
24 Auxiliary low pressure steam (≤ 7 bar)	L2	L2	0[7]	0[7]	0	0	0	0	0[7]	0[7]

LOCATION DEFINITIONS

	Location	Definition
A	Machinery spaces of category A	Machinery spaces of Category A as defined in *Vol 2, Pt 1, Ch 3, 5.1 Machinery spaces*
B	Other machinery spaces	Spaces other than Category A machinery spaces containing propulsion machinery, boilers, steam and internal combustion engines, generators and major electrical machinery, pumps, oil filling stations, refrigerating, stabilising, ventilation and air-conditioning machinery, and similar spaces, and trunks to such spaces.
C	Special category spaces	Spaces and special category spaces as defined in *Vol 2, Pt 9, Ch 1, 1.3 Definitions 1.3.10*
D	Other dry compartments	All spaces other than special category spaces used for stores and equipment and trunks to such spaces
E	f.p. ≤ 60 þC tanks	All spaces used for refuelling fuel and trunks to such spaces
F	Fuel oil tanks	All spaces used for fuel oil and trunks to such spaces

G	Ballast water tanks	All spaces used for ballast water and trunks to such spaces
H	Cofferdams, voids, etc.	Cofferdams and voids are those empty spaces between two bulkheads separating two adjacent compartments
I	Accommodation, service	Accommodation spaces, service spaces and control stations
J	Open decks	Open deck spaces

ABBREVIATIONS

L1 Fire endurance test in dry conditions, 60 minutes. IMO Resolution A.753(18) Appendix 1

L2 Fire endurance test in dry conditions, 30 minutes. IMO Resolution A.753(18) Appendix 1

L3 Fire endurance test in wet conditions, 30 minutes. IMO Resolution A.753(18) Appendix 2

0 No fire endurance test required

N/A Not applicable

X Metallic materials having a melting point greater than 925°C

NOTES

Note 1. Where non-metallic piping is used, remotely controlled valves to be provided at ship's side (valve is to be controlled from outside space).

Note 2. Remote closing valves to be provided at the refuelling tanks.

Note 3. When refuelling tanks contain flammable liquids with f.p. > 60°C, '0' may replace 'N/A' or 'X'.

Note 4. For drains serving only the space concerned, '0' may replace 'L1'.

Note 5. When controlling functions are not required by the rules or Naval requirements, '0' may replace 'L1'.

Note 6. Scuppers serving open decks should be 'X' throughout unless fitted at the upper end with means of closing capable of being operated from a position above the weather deck in order to prevent downflooding.

Note 7. For Mobility and/or Ship Type systems, such as fuel oil tank heating and ship's whistle, 'X' is to replace '0'.

Note 8. Air and sounding pipes on open deck are to be of substantial construction, *see Vol 2, Pt 7, Ch 2, 10.1 Materials 10.1.2*.

11.4.2 The materials used for plastics pipes, except those fitted on open decks and within tanks, cofferdams, void spaces, pipe tunnels and ducts are to have low flame spread characteristics.

11.4.3 The materials used for plastics pipes within accommodation, service and control spaces are not to be capable of producing excessive quantities of smoke and toxic products that may be a hazard to personnel within those spaces.

11.4.4 The Naval Administration may specify to extend the requirements of *Vol 2, Pt 7, Ch 1, 11.4 Fire performance criteria 11.4.3* to apply to equipment piping in machinery spaces. *See also Vol 2, Pt 7, Ch 1, 11.1 General 11.1.8*.

11.4.5 Where a fire protective coating of pipes and fittings is necessary for achieving the fire endurance standards required, the coating is to be resistant to products likely to come into contact with the piping and be suitable for the intended application.

11.5 Electrical conductivity

11.5.1 Where a piping system is required to be electrically conductive for the control of static electricity, the resistance per unit length of the pipe, bends, elbows, fabricated branch pieces, etc. is not to exceed 0,1 MΩ/m, *see also Vol 2, Pt 7, Ch 1, 11.2 Design and performance criteria 11.2.4*.

11.5.2 Electrical continuity is to be maintained across the joints and fittings and the system is to be earthed. *see also Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding* . The resistance to earth from any point in the piping system is not to exceed 1 MΩ.

11.6 Manufacture and quality control

11.6.1 All materials for plastics pipes and fittings are to be approved by LR, and are in general to be tested in accordance with *Ch 14, 4 Plastics pipes and fittings* of the Rules for Materials. For pipes and fittings not employing hand lay up techniques, the hydrostatic pressure test required by *Ch 14, 4.9 Hydraulic test* of the Rules for Materials may be replaced by testing carried out in accordance with the requirements stipulated in a National or International Standard, consistent with the intended use for which the pipe or fittings are manufactured, provided there is an effective quality system in place complying with the requirements of *Ch 14, 4.4 Quality assurance* of the Rules for Materials and the testing is completed to the satisfaction of the LR Surveyor.

11.6.2 The material manufacturer's test certificate, based on actual tested data, is to be provided for each batch of material.

11.6.3 Plastics pipes and fittings are to be manufactured at a works approved by LR in accordance with agreed quality control procedures which shall be capable of detecting at any stage (e.g. incoming material, production, finished article, etc.) deviations in the material, product or process.

11.6.4 Plastics pipes are to be manufactured and tested in accordance with *Ch 14, 4 Plastics pipes and fittings* of the Rules for Materials. For Class III piping systems the pipe manufacturer's test certificate may be accepted in lieu of an LR Certificate and is to be provided for each consignment of pipe.

11.7 Installation and construction

11.7.1 All pipes are to be adequately but freely supported. Suitable provision is to be made for expansion and contraction to take place without unduly straining the pipes.

11.7.2 Pipes may be joined by mechanical couplings or by bonding methods such as welding and laminating.

11.7.3 Where bonding systems are used, the manufacturer or installer shall provide a written procedure covering all aspects of installation, including temperature and humidity conditions. The bonding procedure is to be approved by LR.

11.7.4 The person carrying out the bonding is to be qualified. Records are to be available to the Surveyor for each qualified person showing the bonding procedure and performance qualification, together with dates and results of the qualification testing.

11.7.5 In the case of pipes intended for Mobility or Ship Type systems each qualified person is, at the place of construction, to make at least one test joint, representative of each type of joint to be used. The joined pipe section is to be tested to an internal hydrostatic pressure of four times the design pressure of the pipe system and the pressure held for not less than one hour, with no leakage or separation of joints. The bonding procedure test is to be witnessed by the Surveyor.

11.7.6 Conditions during installation, such as temperature and humidity, which may affect the strength of the finished joints, are to be in accordance with the agreed bonding procedure.

11.7.7 The required fire endurance level of the pipe is to be maintained in way of pipe supports, joints and fittings, including those between plastics and metallic pipes.

11.7.8 Where piping systems are arranged to pass through watertight bulkheads or decks, provision is to be made for maintaining the integrity of the bulkhead or deck, by means of metallic bulkhead or deck pieces. The bulkhead pieces are to be protected against corrosion, and so constructed to be of a strength equivalent to the intact bulkhead: attention is drawn to *Vol 2, Pt 7, Ch 1, 11.7 Installation and construction 11.7.1*. Details of the arrangements are to be submitted for approval.

11.7.9 Where a piping system is required to be electrically conductive, for the control of static electricity, continuity is to be maintained across the joints and fittings, and the system is to be earthed, *see also Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding* .

11.8 Testing

11.8.1 The hydraulic testing of pipes and fittings is to be in accordance with *Vol 2, Pt 7, Ch 1, 7 Copper and copper alloy piping and components*.

11.8.2 Where a piping system is required to be electrically conductive, tests are to be carried out to verify that the resistance to earth from any point in the system does not exceed 1 MΩ. *See also Vol 2, Pt 9, Ch 1, 1.2 Application 1.2.6*.

■ *Section 12*
Valves

12.1 Design requirements

12.1.1 The design, construction and operational capability of valves is to be in accordance with an acceptable National or International Standard appropriate to the piping system. Where valves are not in accordance with an acceptable standard, details are to be submitted for consideration. Where valves are fitted, the requirements of *Vol 2, Pt 7, Ch 1, 12.1 Design requirements 12.1.2* to *Vol 2, Pt 7, Ch 1, 12.1 Design requirements 12.1.8* are to be satisfied.

12.1.2 Valves are to be made of steel, cast iron, copper alloy, or other approved material suitable for the intended purpose.

12.1.3 Valves having isolation or sealing components sensitive to heat are not to be used in spaces where leakage or failure caused by fire could result in fire spread, flooding or the loss of a Mobility system or Ship Type system.

12.1.4 Where valves are required to be capable of being closed remotely in the event of fire, the valves, including their controlgear, are to be of steel construction or of an acceptable fire tested design.

12.1.5 Valves are to be arranged for clockwise closing and are to be provided with indicators showing whether they are open or shut, unless this is readily obvious. Legible nameplates are to be fitted.

12.1.6 Valves are to be so constructed as to prevent the possibility of valve covers or glands being slackened back or loosened when the valves are operated.

12.1.7 Valves are to be used within their specified pressure and temperature rating for all normal operating conditions, and are to be suitable for the intended purpose.

12.1.8 Valves intended for submerged installation are to be suitable for both internal and external media. Spindle sealing is to prevent ingress of external media at the maximum external pressure head expected in service.

■ *Section 13*
Flexible hoses

13.1 General

13.1.1 A flexible hose assembly is a short length of metallic or non-metallic hose normally with prefabricated end fittings ready for installation.

13.1.2 For the purpose of approval for the applications in *Vol 2, Pt 7, Ch 1, 13.2 Applications*, details of the materials and construction of the hoses, and the method of attaching the end fittings together with evidence of satisfactory prototype testing, are to be submitted for consideration. The materials used in the construction of flexible hoses are to be suitable for the intended purposes.

13.1.3 Hose clamps and similar types of end attachments are not be used for flexible hoses in piping systems for steam, flammable media, starting air systems or for sea-water systems where failure may result in flooding. In other piping systems, the use of hose clamps may be accepted where the working pressure is less than 5 bar and provided that there are two clamps at each end connection.

13.1.4 Flexible hoses are to be limited to a length necessary to provide for relative movement between fixed and flexibly mounted items of machinery/equipment or systems.

13.1.5 Flexible hoses are not to be used to compensate for misalignment between sections of piping.

13.1.6 Flexible hose assemblies are not to be installed where they may be subjected to torsional deformation (twisting) under normal operating conditions.

13.1.7 The number of flexible hoses in piping systems mentioned in this section is to be kept to a minimum and to be limited for the purpose stated in *Vol 2, Pt 7, Ch 1, 13.2 Applications 13.2.1*.

13.1.8 Where flexible hoses are intended for use in piping systems conveying flammable fluids, they are not to be installed in close proximity to hot surfaces, electrical installations or other sources of ignition. The risk of ignition due to failure of the hose assembly and subsequent release of fluids is to be mitigated as far as practicable by the use of screens or other suitable protection.

13.1.9 Flexible hoses are to be installed in clearly visible and readily accessible locations.

13.1.10 The installation of flexible hose assemblies is to be in accordance with the manufacturer's instructions and use limitations with particular attention to the following:

(a) Orientation.
(b) End connection support (where necessary).
(c) Avoidance of hose contact that could cause rubbing and abrasion.
(d) Minimum bend radii.

13.1.11 Flexible hoses are to be permanently marked by the manufacturer with the following details:

(a) Hose manufacturer's name or trademark.
(b) Date of manufacture (month/year).
(c) Designation type reference.
(d) Nominal diameter.
(e) Pressure rating.
(f) Temperature rating.

Where a flexible hose assembly is made up of items from different manufacturers, the components are to be clearly identified and traceable to evidence of prototype testing. *See Vol 2, Pt 1, Ch 3, 4.18 Electromagnetic hazards* regarding requirements for a flexible hose register.

13.2 Applications

13.2.1 Short joining lengths of flexible hoses complying with the requirements of this Section may be used, where necessary, to accommodate relative movement between various items of machinery connected to permanent piping systems. The requirements of this Section may also be applied to temporarily-connected flexible hoses or hoses of portable equipment.

13.2.2 Rubber or plastics hoses, with integral cotton or similar braid reinforcement, may be used in fresh and seawater cooling systems. In the case of sea-water systems, where failure of the hoses could give rise to the danger of flooding, the hoses are to be suitably enclosed, as indicated in *Vol 2, Pt 7, Ch 1, 14.2 Applications 14.2.4*.

13.2.3 Rubber hoses, with single, double or more closely woven integral wire braid or other suitable material reinforcement, or convoluted metal pipes with wire braid protection, may be used in bilge, ballast, compressed air, fresh water, sea-water, fuel oil, lubricating oil, Class III steam, hydraulic and thermal oil systems. Flexible hoses of plastics materials for the same purposes, such as Teflon or Nylon, which are unable to be reinforced by incorporating closely woven integral wire braid are to have suitable material reinforcement as far as practicable. Where rubber or plastics hoses are used for fuel oil supply to burners, the hoses are to have external wire braid protection in addition to the integral wire braid. Flexible hoses for use in steam systems are to be of metallic construction.

13.2.4 Flexible hoses are not to be used in high pressure fuel oil injection systems.

13.2.5 The requirements in this Section for flexible hose assemblies are not applicable to hoses intended to be used in fixed fire extinguishing systems.

13.2.6 Short lengths of flexible hoses may be used for acoustic attenuation where agreed by LR. The use of hoses for such applications is to be kept to a minimum.

13.3 Design requirements

13.3.1 Flexible hose assemblies are to be designed and constructed in accordance with recognised National or International Standards acceptable to LR.

13.3.2 Flexible hoses are to be complete with approved end fittings in accordance with manufacturer's specification. End connections which do not have flanges are to comply with *Vol 2, Pt 7, Ch 1, 5.2 Flange connections* as applicable and each type of hose/fitting combination is to be subject to prototype testing to the same standard as that required by the hose with particular reference to pressure and impulse tests.

13.3.3 Flexible hose assemblies intended for installation in piping systems where pressure pulses and/or high levels of vibration are expected to occur in service, are to be designed for the maximum expected impulse peak pressure and forces due to vibration. The tests required by *Vol 2, Pt 7, Ch 1, 13.4 Testing* are to take into consideration the maximum anticipated in-service pressures, vibration frequencies and forces due to installation.

13.3.4 Flexible hose assemblies constructed of non-metallic materials intended for installation in piping systems for flammable media, and sea-water systems where failure may result in flooding, are to be of fire-resistant type. Fire resistance is to be demonstrated by testing to ISO 15540 and ISO 15541.

13.3.5 Flexible hose assemblies are to be suitable for the intended location and application, taking into consideration ambient conditions, compatibility with fluids under working pressure and temperature conditions consistent with the manufacturer's instructions and any other applicable requirements in the Rules.

13.4 Testing

13.4.1 Acceptance of flexible hose assemblies is subject to satisfactory prototype testing of a representative hose assembly. Prototype test programmes for flexible hose assemblies are to be submitted by the manufacturer and are to be sufficiently detailed to demonstrate performance in accordance with the specified standards.

13.4.2 For a particular hose type complete with end fittings, the tests, as applicable, are to be carried out on different nominal diameters for pressure, burst, impulse and fire resistance in accordance with the requirements of the relevant standard. The following standards are to be used as applicable:

- ISO 6802 – *Rubber and plastics hoses and hose assemblies with wire reinforcements – Hydraulic impulse test with flexing*.
- ISO 6803 – *Rubber or plastics hoses and hose assemblies – Hydraulic pressure impulse test without flexing*.
- ISO 15540 – *Ships and marine technology – Fire resistance of hose assemblies – Test methods*.
- ISO 15541 – *Ships and marine technology – Fire resistance of hose assemblies – Requirements for test bench*.
- ISO 10380 – *Pipework – Corrugated metal hoses and hose assemblies*.

Other standards may be accepted where agreed by LR.

13.4.3 All flexible hose assemblies are to be satisfactorily prototype burst tested to an International Standard* to demonstrate they are able to withstand a pressure of not less than four times the design pressure without indication of failure or leakage.

Note The international standards, e.g. EN or SAE for burst testing of non-metallic hoses, require the pressure to be increased until burst without any holding period at 4 x Maximum Working Pressure.

■ *Section 14*
Expansion pieces

14.1 Design and construction requirements

14.1.1 The design and construction of expansion pieces intended for installation in piping systems is to be in accordance with an acceptable standard or design code appropriate to the piping system. Where suitable standards are not available, details of materials and construction are to be submitted for consideration. Where expansion pieces are fitted, the requirements of this section are to be satisfied.

14.1.2 The design of expansion pieces is to take account of pressure, temperature, fluid compatibility, loads to accommodate axial and lateral movements and fatigue life due to vibration.

14.1.3 Prototype pressure tests are to be carried out on each new type of expansion piece, and in no case is the burst pressure to be less than four times the design pressure.

14.1.4 For requirements relating to testing after manufacture, *see Vol 2, Pt 7, Ch 1, 16 Testing*.

14.2 Applications

14.2.1 Expansion pieces of an acceptable design are only to be used in permanent piping system installations to accommodate axial and lateral movements. They are not to be used to compensate for piping misalignment unless specifically designed for the purpose.

14.2.2 Expansion pieces are to be used within their specified pressure, temperature and movement conditions for all normal operating conditions. The design and operating ratings of expansion pieces are not to be less than that of the piping system in which the expansion piece is installed.

14.2.3 Expansion pieces used in compressed air, boiler feed water, steam and flammable oil piping systems are to be of steel or other approved material.

14.2.4 Expansion pieces incorporating oil resistant rubber or other suitable synthetic material may be used in cooling water lines in machinery spaces. Where fitted in sea-water lines, they are to be provided with guards which effectively enclose, but do not interfere with, the action of the expansion pieces and will reduce to a minimum practicable, any flow of water into the machinery spaces in the event of failure of the flexible elements. Proposals to use such fittings in water lines in other services, including, ballast lines in machinery spaces and inside water ballast tanks, and bilge lines in enclosed spaces only, will be specially considered when plans of the piping systems are submitted for approval.

14.2.5 Expansion pieces are to be installed in accordance with the manufacturer's instructions and are to be protected against over extension and over compression. The adjoining pipes are to be suitably aligned, supported and anchored. Where necessary, expansion pieces of bellows are to be protected against mechanical damage.

■ *Section 15* **Pumps**

15.1 General

15.1.1 The design, construction and operational capability of all pumping units is to be suitable for operating conditions in *Vol 2, Pt 1, Ch 3, 4 Operating conditions*. The selection of pumping units is to recognise the following details:

(a) Pump characteristic and required duty.
(b) Performance if required to perform a secondary duty.
(c) Pumped fluid and its temperature ranges.
(d) Maximum discharge pressure head from the pump and design pressure of piping system.
(e) The size of air pipes and capacity of air pipe heads fitted to tanks which can be pumped up.
(f) The need to fit relief devices to pumps and piping systems.
(g) Maximum permissible fluid velocities in the piping system to avoid erosion and damage to valve seats and other fittings.
(h) Minimum fluid velocities to avoid fouling and subsequent pitting.

15.1.2 Pumps employed in bilge pumping systems are to have a means of priming and this is to be independent of the pump sea inlet connection.

■ *Section 16* **Testing**

16.1 Hydraulic tests before installation on board

16.1.1 All Class I and II pipes and their associated fittings are to be tested by hydraulic pressure to the Surveyor’s satisfaction. Further, all steam, feed, compressed air and fuel oil pipes, together with their fittings, are to be similarly tested where the design pressure is greater than 7,0 bar. The test is to be carried out after completion of manufacture and before installation on board and, where applicable, before insulating and coating.

16.1.2 Where the design temperature does not exceed 300°C, the test pressure is to be 1,5 times the design pressure, as defined in *Vol 2, Pt 7, Ch 1, 3.3 Design pressure*.

16.1.3 Where testing of systems or sub-systems following final assembly is specified, in addition to the requirements of *Vol 2, Pt 7, Ch 1, 16.1 Hydraulic tests before installation on board 16.1.2* the lowest applicable pressure as defined in this sub- Section is to be used for testing.

16.1.4 For steel pipes and integral fittings for use in systems where the design temperature exceeds 300°C, the test pressure is to be as follows:

(a) For carbon and carbon-manganese steel pipes, the test pressure is to be twice the design pressure, as defined in *Vol 2, Pt 7, Ch 1, 3.3 Design pressure*.
(b) For alloy steel pipes, the test pressure is to be determined by the following formula, but need not exceed 2*p*:

$$p_{\mathrm{t}} = 1,5 \frac{\sigma_{100}}{\sigma} p \text{ bar}$$

where

= p_{t} and p are as defined in *Vol 2, Pt 7, Ch 1, 3.2 Design symbols 3.2.1*

σ = permissible stress for the design temperature, in N/mm^2, as stated in *Table 1.6.2 Alloy steel pipes*

σ_{100} = permissible stress for 100°C, in N/mm^2, as stated in *Table 1.6.2 Alloy steel pipes*.

16.1.5 Where alloy steels not included in *Table 1.6.2 Alloy steel pipes* are used, the permissible stresses will be specially considered, as indicated in *Vol 2, Pt 7, Ch 1, 6.1 Wrought steel pipes and bends 6.1.2*.

16.1.6 Consideration will be given to the reduction of the test pressure to not less than 1,5*p*, where it is necessary to avoid excessive stress in way of bends, branches, etc.

16.1.7 Valves and fittings non-integral with the piping system, intended for Classes I and II, are to be tested in accordance with recognised standards, but to not less than 1,5 times the design pressure. Where design features are such that modifications to the test requirements are necessary, alternative proposals for hydraulic tests are to be submitted for special consideration.

16.1.8 For requirements relating to valves and cocks intended to be fitted on the ship's side below the load water line, *see Vol 2, Pt 7, Ch 2, 2.5 Ship-side valves and fittings (other than those on scuppers and sanitary discharges) 2.5.10*.

16.1.9 In no case is the membrane stress to exceed 90 per cent of the yield stress at the testing temperature.

16.2 Testing after assembly on board

16.2.1 Heating coils in tanks, gas fuel and fuel oil piping are to be tested by hydraulic pressure, after installation on board, to 1,5 times the design pressure but in no case to less than 4 bar.

16.2.2 Where pipes specified in *Vol 2, Pt 7, Ch 1, 16.1 Hydraulic tests before installation on board 16.1.1* are butt welded together during assembly on board, they are to be tested by hydraulic pressure in accordance with the requirements of *Vol 2, Pt 7, Ch 1, 16.1 Hydraulic tests before installation on board* after welding. The pipe lengths may be insulated, except in way of the joints made during installation and before the hydraulic test is carried out.

16.2.3 The hydraulic test required by *Vol 2, Pt 7, Ch 1, 16.2 Testing after assembly on board 16.2.2* may be omitted provided non-destructive tests by ultrasonic or radiographic methods are carried out on the entire circumference of all butt welds with satisfactory results. Where ultrasonic tests have been carried out, the manufacturer is to provide the Surveyor with a signed statement confirming that ultrasonic examination has been carried out by an approved operator and that there were no indications of defects which could be expected to have prejudicial effect on the service performance of the piping.

16.2.4 Where bilge pipes are accepted in way of double bottom tanks or deep tanks, the pipes after fitting are to be tested by hydraulic pressure to the same pressure as the tanks through which they pass.

16.2.5 Each flexible hose assembly and expansion piece intended for use with flammable liquids is to be provided with a certificate of hydrostatic pressure testing and conformity of production.

16.2.6 Where flexible hoses, mechanical pipe connections and/or expansion pieces are used in bilge, dewatering, sea water or flammable liquid piping systems, the pipe system is to be hydraulically tested to 1,5 times the design pressure or 7 bar whichever is the greater.

16.2.7 Pumps essential for the propulsion or safety of the ship are to be tested by hydraulic pressure to 1,5 times the nominal pressure rating at ambient temperature.

■ *Section 17*
Guidance notes on metal pipes for water service

17.1 General

17.1.1 These guidance notes, except where it is specifically stated, apply to sea-water piping systems.

17.1.2 1In addition to the selection of suitable materials, careful attention should be given to the design details of the piping system and the workmanship in fabrication, construction and installation of the pipework in order to obtain maximum life in service.

17.2 Materials

17.2.1 Materials used in sea-water piping systems include:

- Galvanised steel.
- Steel pipes lined with rubber, plastics or stoved coatings.

- Copper.
- 90/10 copper-nickel-iron.
- 70/30 copper-nickel.
- Aluminium brass.

17.2.2 Selection of materials should be based on all of the following:

- The ability to resist general and localised corrosion, such as pitting, impingement attack and cavitation throughout all the flow velocities likely to be encountered.
- Compatibility with the other materials in the system, such as valve bodies and casings, e.g. in order to minimise bimetallic corrosion.
- The ability to resist selective corrosion, e.g. dezincification of brass, dealminification of aluminium brass and graphitisation of cast iron, the ability to resist stress corrosion and corrosion fatigue.
- The amenability to fabrication by normal practices.

17.3 Steel pipes

17.3.1 Steel pipes should be protected against corrosion, and protective coatings should be applied on completion of all fabrication, i.e. bending, forming and welding of the steel pipes.

17.3.2 Welds should be free from lack of fusion and crevices. The surfaces should be dressed to remove slag and spatter and this should be done before coating. The coating should be continuous around the ends of the pipes and on the faces of flanges.

17.3.3 Galvanising the bores and flanges of steel pipes as protection against corrosion is common practice, and is recommended as the minimum protection for pipes in sea-water systems, including those for bilge and ballast service.

17.3.4 Austenitic stainless steel pipes are not recommended for salt-water services as they are prone to pitting, particularly in polluted waters.

17.3.5 Rubber lined pipes are effective against corrosion and suitable for higher water velocities. The rubber lining should be free from defects, e.g. discontinuities, pinholes, etc. and it is essential that the bonding of the rubber to the bore of the pipe and flange face is sound. Rubber linings should be applied by firms specialising in this form of protection.

17.3.6 The foregoing comments on rubber lined pipes also apply to pipes lined with plastics.

17.3.7 Stove coating of pipes as protection against corrosion should only be used where the pipes will be efficiently protected against mechanical damage.

17.4 Copper and copper alloy pipes

17.4.1 Copper pipes are particularly susceptible to perforation by corrosion/erosion and should only be used for low water velocities and where there is no excessive local turbulence.

17.4.2 Aluminium brass and copper-nickel-iron alloy pipes give good service in reasonably clean sea-water. For service with polluted river or harbour waters, copper-nickel-iron alloy pipes with at least 10 per cent nickel are preferable. Alpha-brasses, i.e. those containing 70 per cent or more copper, must be inhibited effectively against dezincification by suitable additions to the composition. Alpha beta-brasses, i.e. those containing less than 70 per cent copper, should not be used for pipes and fittings.

17.4.3 New copper alloy pipes should not be exposed initially to polluted water. Clean sea-water should be used at first to allow the metals to develop protective films. If this is not available the system should be filled with inhibited town mains water.

17.5 Flanges

17.5.1 Where pipes are exposed to sea-water on both external and internal surfaces, flanges should be made, preferably, of the same material. Where sea-water is confined to the bores of pipes, flanges may be of the same material or of less noble metal than that of the pipe.

17.5.2 Fixed or loose type flanges may be used. The fixed flanges should be attached to the pipes by fillet welds or by capillary silver brazing. Where welding is used, the fillet weld at the back should be a strength weld and that in the face, a seal weld.

17.5.3 Inert gas shielded arc welding is the preferred process but metal arc welding may be used on copper-nickel-iron alloy pipes.

17.5.4 Mild steel flanges may be attached by argon arc welding to copper-nickel-iron pipes and give satisfactory service, provided that no part of the steel is exposed to the sea-water.

17.5.5 Where silver brazing is used, strength should be obtained by means of the bond in a capillary space over the whole area of the mating surfaces. A fillet braze at the back of the flange or at the face is undesirable. The alloy used for silver brazing should contain not less than 49 per cent silver.

17.5.6 The use of a copper-zinc brazing alloy is not permitted.

17.6 Water velocity

17.6.1 Water velocities should be carefully assessed at the design stage and the materials of pipes, valves, etc. selected to suit the conditions.

17.6.2 The water velocity in copper pipes should not exceed 1 m/s.

17.6.3 The water velocity in the pipes of the materials below should normally be not less than about 1 m/s in order to avoid fouling and subsequent pitting, but should not be greater than the following:

- Galvanised steel 3,0 m/s
- Aluminium brass 3,0 m/s
- 90/10 copper-nickel-iron 3,5 m/s
- 70/30 copper-nickel 5,0 m/s

17.7 Fabrication and installation

17.7.1 Attention should be given to ensuring streamlined flow and reducing entrained air in the system to a minimum. Abrupt changes in the direction of flow, protrusions into the bores of pipes and other restrictions of flow should be avoided. Branches in continuous flow lines should be set at a shallow angle to the main pipe, and the junction should be smooth. The following points should be observed:

(a) Short stiff bends are to be avoided, *see Vol 2, Pt 7, Ch 1, 17.7 Fabrication and installation 17.7.4*.
(b) Pipe runs downstream of turbulence raising components such as reducing valves and orifices are to be straight and as long as practicable.
(c) Changes in pipe bore dimensions are to have a shallow taper transition.

17.7.2 Pipe bores should be smooth and clean.

17.7.3 Jointing should be flush with the bore surfaces of pipes and misalignment of adjacent flange faces should be reduced to a minimum.

17.7.4 Pipe bends should be of as large a radius as possible (in general, the radius of curvature at centreline is to be not less than three times the pipe outside diameter) and the bore surfaces should be smooth and free from puckering at these positions. Any carbonaceous films or deposits formed on the bore surfaces during the bending processes should be carefully removed. Organic substances are not recommended for the filling of pipes for bending purposes.

17.7.5 The position of supports should be given special consideration in order to minimise vibration and ensure that excessive bending moments are not imposed on the pipes.

17.7.6 Systems should not be left idle for long periods, especially where the water is polluted.

17.7.7 Strainers should be provided at the inlet to seawater systems.

17.7.8 Where pipes and associated fittings are required to be thermally insulated after installation on board, the piping should be arranged to permit efficient application of insulating materials.

17.7.9 Non-ferrous piping should not be arranged within bilge wells or spaces. Where this is not possible, the piping should be suitably treated to avoid galvanic action in the bilge spaces.

17.8 Metal pipes for fresh water services

17.8.1 Mild steel or copper pipes are normally satisfactory for service in fresh water applications. Hot fresh water, however, may promote corrosion in mild steel pipes unless the hardness and pH of the water are controlled.

17.8.2 Water with a slight salt content should not be left stagnant for long periods in mild steel pipes. Low salinity and the limited supply of oxygen in such conditions promote the formation of black iron oxide, and this may give rise to severe pitting. Where stagnant conditions are unavoidable, steel pipes should be galvanised, or pipes of suitable non-ferrous material used.

17.8.3 Copper alloy pipes should be treated to remove any carbonaceous films or deposits before the tubes are put into service.

17.8.4 Brass fittings and flanges in contact with water should be made of an alpha-brass effectively inhibited against dezincification by suitable additions to the composition.

17.8.5 Aluminium brass has been widely used as material for heat exchanger and condenser tubes, but its use in 'once through' systems is not recommended since, under certain conditions, it is prone to pitting and cracking.

17.8.6 Piping systems for potable water are to be designed to avoid dead ends and other configurations that would lead to stagnant conditions.

■ *Section 18* **Heat exchangers**

18.1 General

18.1.1 The requirements in this Section are applicable to heat exchangers of the shell and tube type and plate type and which are necessary for the operation of Mobility and Ship Type engineering systems.

18.1.2 The requirements of this Section are with the goal of providing heat exchange capability whereby normal operation of Mobility and Ship Type engineering systems can be sustained or restored when the performance of the heat exchanger has become degraded due to operating in normal sea-going conditions.

18.1.3 The number, type and capability rating of heat exchangers installed for Mobility and Ship Type engineering systems are to be adequate for all envisaged operating conditions taking into account all relevant ambient environmental conditions that may affect the performance of a heat exchanger.

18.1.4 Heat exchangers are to be installed such that where sea water is used for cooling purposes, the suction pipes to the supply pumps are to be provided with strainers which can be cleaned without interruption to the cooling water supply to the heater exchanger.

18.1.5 The design of heat exchangers is to be in accordance with an applicable and recognised standard acceptable to LR.

18.1.6 Heat exchangers are to be capable of stable operation at their specified rating under all envisaged operating conditions, *see Vol 2, Pt 1, Ch 3, 4 Operating conditions*. Any degraded performance under extreme environmental operating conditions is to be stated by the manufacturer and included in the System Design Description required by *Vol 2, Pt 7, Ch 1, 18.1 General 18.1.11*.

18.1.7 The selection of heat exchangers is to recognise the required functional performance of their intended duty in terms of effective heat transfer capacity, fluid media, fluid design flow rates and pressures, and, also recognise the design coefficient of heat transfer in different fouled conditions. *See also Vol 2, Pt 7, Ch 1, 15.1 General 15.1.1*.

18.1.8 Heat exchangers are to be capable of being cleaned when installed onboard. They are to be installed such that there are adequate access arrangements to permit cleaning and maintenance in accordance with the manufacturer's instructions.

18.1.9 To provide for venting of entrapped air from heat exchangers, high points on each fluid side of the heat exchanger not otherwise vented by fluid branches are provided with an air vent connection. Each air vent is to include a valve attached to the heat exchanger.

18.1.10 Heat exchangers are to be type tested in accordance with a specification acceptable to LR.

18.1.11 A System Design Description for each size and type of heat exchanger used in Mobility and Ship Type engineering systems is to be submitted for information purposes. The System Design Description is to include details of margins for fouling and plugging of tubes where applicable.

18.2 Materials

18.2.1 Materials used in the construction of heat exchangers are to be manufactured and tested in accordance with the requirements of the*Rules for the Manufacture, Testing and Certification of Materials, July 2015*. For requirements of copper and copper alloy tubes intended for use in heat exchangers, *see Ch 9, 3 Tubes* of the Rules for Materials.

18.2.2 Materials of heat exchangers are to be compatible with, and offer suitable erosion and corrosion resistance against, the intended fluid media. *See also Vol 2, Pt 7, Ch 1, 17 Guidance notes on metal pipes for water service*. Sea-water wetted surfaces are to be non-ferrous or coated with a suitable rubber or plastic material where they are not part of the heat exchange system.

18.2.3 Means are to be provided to enable non-ferrous materials to be protected against the effects of exposure to polluted cooling water.

18.2.4 Combinations of incompatible materials are to be avoided, including those of the system pipe work in which the heat exchanger is to be fitted.

18.3 Shell and tube type heat exchangers

18.3.1 The design of shell, end boxes and fluid openings in shell and tube type heat exchangers is to ensure:

(a) Uniform distribution of fluids over and through the tubes.
(b) A smooth flow of the fluids from the inlet pipes to the tubes and from the tubes to the outlet pipes. In particular end boxes are to have sufficient depth to allow fluid to travel freely to all tubes. The minimum end box depth is to be at least equivalent to the internal diameter of the inlet/outlet connecting pipes.
(c) That pockets or obstructions which might interfere with fluid flow are avoided.
(d) That the water velocity complies with *Vol 2, Pt 7, Ch 1, 17.6 Water velocity 17.6.3*.
(e) That the form of hand holes and sight holes on end boxes preclude the formation of eddies.
(f) That the inclusion of internal ribs to provide a means of strengthening is avoided. However, there is to be sufficient support to avoid vibration of tubes in the tube-bundle which may detrimentally affect their specified life.
(g) That positive drainage of heat exchangers is provided. Drain valves, or for small heat exchangers drain plugs, are to be provided to ensure that tubes and shells are emptied and no large quantities of fluid are trapped in end boxes and shells.

18.3.2 Shell and tube type heat exchangers are to be arranged in the ship such that tube plates are readily accessible for cleaning/inspection and to allow for withdrawal of tubes for replacement without disturbing adjacent machinery.

18.3.3 Where ever practicable, viewing ports are to be provided on heat exchanger shell end boxes or covers to permit visual inspection of tubes, baffles and tube plates. In general, this will be limited to larger units of over 300 mm internal shell dimension.

18.4 Plate type heat exchangers

18.4.1 The design of the fluid openings and plates of plate type heat exchangers is to ensure:

(a) Uniform distribution of fluids through the plate passages.
(b) That pockets or obstructions which might interfere with fluid flow are avoided.
(c) Positive drainage of heat exchangers is provided. Drain valves, or for small heat exchangers drain plugs, are to be provided to ensure complete drainage.

18.4.2 Plate type heat exchangers are to be arranged in the ship such that plates are readily accessible for cleaning/inspection and to allow for withdrawal of plates for replacement with the minimum disturbance of adjacent pipe work.

18.5 Hydraulic testing

18.5.1 In general, heat exchangers are to be tested hydraulically to 1,5 times their maximum working pressures on the tube and shell sides or on both sides of the heat transfer plates as appropriate.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter covers the requirements for ship piping systems installed in naval ships for the watertight and weathertight integrity of the hull and spaces within the hull.

1.1.2 Consideration will be given to special cases or to arrangements which are equivalent to those required by these Rules. Consideration will also be given to the piping system arrangements of small ships and ships to be assigned class notations for restricted or special services.

1.1.3 Where ship piping systems are required to satisfy requirements for the prevention of pollution, reference is to be made to the applicable requirements for **POL** and **ENV** class notations. *See Vol 3, Pt 3, Ch 6 Pollution Prevention* and *Vol 3, Pt 2, Ch 2 Environmental Protection*.

1.2 Documentation required for design review

1.2.1 At least three copies of the following plans (in diagrammatic form) and a System Design Description containing the additional information are to be submitted for approval. Additional plans should not be submitted unless the arrangements are of a novel or special character affecting classification:

- Arrangements of air pipes and closing appliances to tanks and enclosed spaces.
- Sounding arrangements for all tanks and enclosed spaces.
- Arrangements of level alarms fitted in tanks, machinery spaces and any other spaces.
- Arrangements of any cross-flooding or heeling tank systems.
- Bilge drainage and dewatering arrangements to all compartments which are to include details of location, number and capacity of pumping units on bilge and dewatering service.
- Ballast filling and drainage arrangements. The submission should include a schematic piping drawing showing connection of the ballast water treatment system, where fitted, to the ballast filling and drainage arrangement.
- Tank overflow arrangements.
- Details verifying compliance with the sizing of air pipes required by *Vol 2, Pt 7, Ch 2, 10.8 Overflow pipes*.
- Details verifying compliance with *Vol 2, Pt 7, Ch 2, 10.3 Air pipes 10.3.3* for tanks that can be replenished at sea with design ship movements and filling rates stated.

- Operating manuals and maintenance instructions are to be provided on board and submitted for information where requested by Lloyd's Register (hereinafter referred to as 'LR'). The manuals are to include particulars, description, operating instructions and maintenance instructions for all systems.

1.3 Prevention of progressive flooding in damage condition

1.3.1 Precautions are to be taken to prevent progressive flooding between compartments resulting from damage to piping systems. For this purpose, piping systems are to be located inboard of the assumed extent of damage.

1.3.2 Where it is not practicable to locate piping systems as required by *Vol 2, Pt 7, Ch 2, 1.3 Prevention of progressive flooding in damage condition 1.3.1*, the following precautions are to be taken:

(a) Bilge and dewatering suction pipes are to be provided with non-return valves of approved type.

(b) Other piping systems are to be provided with shut-off valves capable of being operated from positions accessible in the damage condition, or from above the damage waterline where required by the Rules. These valves are to be located in the compartment containing the open end or in a suitable position such that the compartment may be isolated in the event of damage to the piping system.

1.3.3 Where penetration of watertight divisions by pipes, ducts, trunks or other penetrations is necessary, arrangements are to be made to maintain the watertight integrity.

■ *Section 2* Construction and installation

2.1 Materials

2.1.1 Except where otherwise stated in this Chapter, pipes, valves and fittings are to be made of steel, cast iron, copper, copper alloy, or other approved material suitable for the intended service.

2.1.2 Where applicable, the materials are to comply with the relevant requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements*.

2.1.3 Materials sensitive to heat, such as aluminium or plastics, are not to be used in systems essential to the safe operation of the ship, or for containing combustible liquids or sea-water where leakage or failure could result in fire or in the flooding of watertight compartments. *See Vol 2, Pt 7, Ch 1 Piping Design Requirements* for plastics pipes.

2.2 Pipe wall thickness

2.2.1 The minimum nominal wall thickness of steel, copper and copper alloy pipes is to be in accordance with *Vol 2, Pt 7, Ch 1 Piping Design Requirements*.

2.2.2 Special consideration will be given to the wall thickness of pipes made of materials other than steel, copper and copper alloy.

2.3 Valves - Installation and control

2.3.1 Valves and cocks are to be fitted in places where they are at all times readily accessible, unless otherwise specifically mentioned in the Rules. Valves in ballast systems may be fitted inside tanks, subject to *Vol 2, Pt 7, Ch 2, 2.3 Valves - Installation and control 2.3.2*.

2.3.2 All valves which are provided with remote control arrangements are to be arranged for local manual operation, independent of the remote operating mechanism. For shipside valves and valves on the collision bulkhead, the means for local manual operation are to be permanently attached. For submerged valves in ballast systems, as permitted by *Vol 2, Pt 7, Ch 2, 2.3 Valves - Installation and control 2.3.1*, local manual operation may be by extended spindle, a portable hand pump or similar energy device. Where manual operation is by hand pump or stored energy device, the control lines to each submerged valve are to incorporate quick coupling connections, as close to the valve actuator as practicable, to allow easy connection of the hand pump or stored energy device. No fewer than two hand pumps or stored energy devices are to be available for each space where valves can be locally and remotely operated.

2.3.3 In case of valves which are required by the Rules to be provided with remote control, opening and/or closing of the valves by local manual means is not to render the remote control system inoperable.

2.4 Attachment of valves to watertight plating

2.4.1 Valve chests, cocks, pipes or other fittings attached direct to the plating of tanks, and to bulkheads, flats or tunnels which are required to be of watertight construction, are to be secured by means of studs screwed through the plating or by tap bolts, and not by bolts passing through clearance holes. Alternatively, the studs or the bulkhead piece may be welded to the plating.

2.4.2 For requirements relating to valves on the collision bulkhead, *see Vol 2, Pt 7, Ch 2, 3.3 Fore and after peaks 3.3.3*.

2.5 Ship-side valves and fittings (other than those on scuppers and sanitary discharges)

2.5.1 All sea inlet and overboard discharge pipes are to be fitted with valves or cocks secured direct to the shell plating, or to the plating of fabricated steel water boxes attached to the shell plating. These fittings are to be secured by bolts tapped into the plating and fitted with countersunk heads, or by studs screwed into heavy steel pads fitted to the plating. The stud holes are not to penetrate the plating.

2.5.2 Valves for ship-side applications are to be installed such that the section of piping immediately inboard of the valve can be removed without affecting the watertight integrity of the hull.

2.5.3 Distance pieces of short, rigid construction, and made of approved material, may be fitted between the valves and shell plating. Distance pieces of steel may be welded to the shell plating. Details of the welded connections and of fabricated steel water boxes are to be submitted.

2.5.4 Gratings are to be fitted at all openings in the ship's side for sea inlet valves and inlet water boxes. The net area through the gratings is to be not less than twice that of the valves connected to the sea inlets, and provision is to be made for clearing the gratings by use of low pressure steam or compressed air, *see Vol 2, Pt 7, Ch 2, 2.5 Ship-side valves and fittings (other than those on scuppers and sanitary discharges) 2.5.5*.

2.5.5 All suction and discharge valves and cocks secured direct to the shell plating of the ship are to be fitted with spigots passing through the plating, but the spigots on the valves or cocks may be omitted if these fittings are attached to pads or distance pieces which themselves form spigots in way of the shell plating. Blow-down valves or cocks are also to be fitted with a protection ring through which the spigot is to pass, the ring being on the outside of the shell plating. Where alternative forms of attachment are proposed, details are to be submitted for consideration.

2.5.6 Blow-down valves or cocks on the ship's side are to be fitted in accessible positions above the level of the working platform, and are to be provided with indicators showing whether they are open or shut. Cock handles are not to be capable of being removed unless the cocks are shut, and, if valves are fitted, the hand wheels are to be suitably retained on the spindle.

2.5.7 Sea inlet and overboard discharge valves and cocks are in all cases to be fitted in easily accessible positions and, so far as practicable, are to be readily visible. Indicators are to be provided local to the valves and cocks, showing whether they are open or shut. Provision is to be made for preventing any discharge of water into rescue boats. The valve spindles are to extend above the lower platform, and the hand wheels of the main cooling water sea inlet and emergency drainage suction valves are to be situated not less than 460 mm above this platform.

2.5.8 Ship-side valves and fittings, if made of steel or other approved material with low corrosion resistance, are to be suitably protected against wastage.

2.5.9 The scantlings of valves and valve stools fitted with steam or compressed air clearing connections are to be suitable for the maximum pressure to which the valves and stools may be subjected.

2.5.10 Valves, cocks and distance pieces, intended for installation on the ship's side below the waterline, are to be tested by hydraulic pressure to not less than 5 bar.

2.5.11 For sea connections for ships having notation for ice navigation, *see Vol 3, Pt 1, Ch 1 Ice Navigation - First-Year Ice Conditions*.

2.6 Piping systems — Installation

2.6.1 Bilge, dewatering, ballast and cooling water suction and discharge pipes are to be permanent pipes made in readily removable lengths with flanged joints are to be efficiently secured in position to prevent chafing or lateral movement. For joints in fuel oil piping systems, *see Vol 2, Pt 7, Ch 3, 4.5 Pipes conveying heated oil* and *Vol 2, Pt 7, Ch 3, 4.6 Low pressure pipes*.

2.6.2 Where lack of space prevents the use of normal circular flanges, details of the alternative methods of joining the pipes are to be submitted.

2.6.3 Long or heavy lengths of pipes are to be supported by bearers so that no undue load is carried by the flanged connections of the pumps or fittings to which they are attached.

2.7 Provision for expansion

2.7.1 Suitable provision for expansion is to be made, where necessary, in each range of pipes, *see Vol 2, Pt 7, Ch 1, 14 Expansion pieces*.

2.8 Miscellaneous requirements

2.8.1 All pipes situated where they are liable to mechanical damage are to be efficiently protected.

2.8.2 So far as practicable, pipelines, including exhaust pipes from oil engines, are not to be led in the vicinity of switchboards or other electrical appliances in positions where the drip or escape of liquid, gas or steam from joints or fittings could cause damage to the electrical installation. Where it is not practicable to comply with these requirements, drip trays or shields are to be provided as found necessary. Short sounding pipes to tanks are not to terminate near electrical appliances, *see Vol 2, Pt 7, Ch 2, 10.4 Termination of air pipes 10.4.2*.

2.9 Testing after installation

2.9.1 After installation on board, all steam, hydraulic, compressed air and other piping systems within the Mobility and Ship Type category, together with associated fittings which are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

2.10

2.10.1 For guidance on metal pipes for water services, *see Vol 2, Pt 7, Ch 1, 17 Guidance notes on metal pipes for water service*

■ *Section 3*
Drainage of compartments, other than machinery spaces

3.1 General

3.1.1 All ships are to be provided with efficient dewatering arrangements, having suctions and means for drainage so arranged that any water within any compartment of the ship, or any watertight section of any compartment, can be pumped out through at least one suction when the ship is on an even keel and is either upright or has a list of not more than 5°. For this purpose, wing suctions will generally be necessary, except in short, narrow compartments where one suction can provide effective drainage under the above conditions.

3.1.2 The dewatering system arrangements are to be capable of draining any watertight compartment under all practicable conditions after a casualty, whether the ship is upright or listed.

3.1.3 The requirements for dewatering system arrangements recognise that naval ships commonly use eductors for dealing with large amounts of water ingress into machinery spaces and other compartments.

3.1.4 Bilge piping systems for dealing with small amounts of oily water accumulation in machinery spaces and installed for the prevention of pollution of the sea by oil are not considered an effective means of dealing with large amounts of water ingress referred to in *Vol 2, Pt 7, Ch 2, 3.1 General 3.1.3*. The arrangement of valves and fittings is however, to comply with the requirements of *Vol 2, Pt 7, Ch 2, 7 Pipe systems and their fittings* for the prevention of communication between compartments.

3.1.5 Where it is intended to carry flammable or toxic liquids in enclosed spaces, the bilge system shall be designed to prevent pumping of such liquids through piping and pumps in machinery or other spaces where a source of ignition may exist. Depending on the quantities of such liquids carried, an additional means of drainage may be required for their compartments.

3.1.6 For a normally inaccessible small void compartment, such as an echo sounding compartment, which is accessed from within a normally inaccessible space, such as a forepeak tank, alternative drainage arrangements to those required by *Vol 2, Pt 7, Ch 2, 3.1 General 3.1.1* may be considered. For such arrangements, a warning notice is to be located in a prominent position

specifying the precautions to be taken prior to opening the manhole of the small void compartment. Means are to be provided to indicate flooding of the compartment without opening, such as fitting indicator plugs to the manhole. Drainage arrangements are to be submitted to LR for approval.

3.2 Tanks and cofferdams

3.2.1 All tanks (including double bottom tanks), whether used for ballast or fuel oil, are to be provided with suction pipes, led to suitable power pumps, from the after end of each tank. Ballast tanks may be drained by the use of eductors and filled by using a suitable sea water supply system. Where the sea water supply system for filling ballast tanks is used for other purposes, the availability of supply is to be sufficient for all operational requirements.

3.2.2 In general, the drainage arrangements are to be in accordance with *Vol 2, Pt 7, Ch 2, 3.1 General*. However, where the tanks are divided by longitudinal watertight bulkheads or girders into two or more tanks, a single suction pipe, led to the after end of each tank, will normally be acceptable.

3.2.3 Similar drainage arrangements are to be provided for cofferdams, except that the suctions may be led to the bilge or dewatering system.

3.3 Fore and after peaks

3.3.1 Fuel oil, lubrication oil and other flammable liquids are not to be carried in forepeak tanks.

3.3.2 Where the peaks are used as tanks, a power pump or suitable eductor suction is to be led to each tank, except in the case of small tanks used for the carriage of domestic fresh water, where hand pumps may be used.

3.3.3 Where the peaks are not used as tanks, and bilge or dewatering suctions are not fitted, drainage of both peaks may be effected by hand pump suctions, provided that the suction lift is well within the capacity of the pumps and in no case exceeds 7,3 m.

3.3.4 Pipes piercing the collision bulkhead are to be fitted with suitable valves operable from above the damage control deck. The valve chest is to be fitted to the aft side of the bulkhead unless the use of that space precludes the valve being readily accessible in all service conditions. In such cases the valve chest may be secured to the bulkhead inside the fore peak.

3.4 Space above fore, after peaks and machinery spaces

3.4.1 Provision is to be made for the drainage of the chain locker and watertight compartments above the fore peak tank by hand pump, power pump or eductor suctions.

3.4.2 Steering gear compartments or other small enclosed spaces situated above the after peak tank are to be provided with suitable means of drainage, either by hand pump, power pump or eductor suctions.

3.4.3 Subject to special approval of any applicable subdivision requirements, compartments referred to in *Vol 2, Pt 7, Ch 2, 3.3 Fore and after peaks 3.3.2* that are adequately isolated from the adjacent tween decks, may be drained by scuppers of not less than 38 mm bore, discharging to the tunnel (or machinery space in the case of ships with machinery aft) and fitted with self-closing cocks situated in well lighted and visible positions.

3.5 Maintenance of integrity of bulkheads

3.5.1 The intactness of the machinery space bulkheads, and of tunnel plating required to be of watertight construction, is not to be impaired by the fitting of scuppers discharging to machinery space or tunnels from adjacent compartments which are situated below the bulkhead deck. These scuppers may, however, be led into a strongly constructed scupper drain tank situated in the machinery space or tunnel, but closed to these spaces and drained by means of a suction of appropriate size led from the bilge or dewatering system through a screw-down non-return valve.

3.5.2 The scupper tank air pipe is to be led to above the bulkhead deck, and provision is to be made for ascertaining the level of water in the tank.

3.5.3 Where one tank is used for the drainage of several watertight compartments, the scupper pipes are to be provided with screw-down non-return valves.

3.5.4 No open ended drain valve or cock is to be fitted to the collision bulkhead. Drain valves or cocks are not to be fitted to other watertight bulkheads if alternative means of drainage are practicable.

3.5.5 Where drain valves or cocks are fitted to bulkheads other than the collision bulkhead, as permitted by *Vol 2, Pt 7, Ch 2, 3.5 Maintenance of integrity of bulkheads 3.5.4*, the drain valves or cocks are to be at all times readily accessible and are to be

capable of being shut off from positions above the bulkhead deck. Indicators are to be provided to show whether the drains are open or shut.

■ *Section 4*
Drainage of machinery spaces

4.1 General

4.1.1 The dewatering arrangements in the machinery spaces are to comply with *Vol 2, Pt 7, Ch 1, 3.1 Design and construction*, except that the arrangements are to be such that any water which may enter these compartments can be drained through at least two dewatering suctions when the ship is on an even keel, and is either upright or has a list of not more than 5°. The two means of drainage are to be capable of being operated independently of each other.

4.1.2 The drainage arrangements are to be such that machinery spaces can be pumped out under all practical conditions after a casualty, whether the ship is upright or listed.

4.1.3 In ships propelled by electrical machinery, special means are to be provided to prevent the accumulation of bilge water under the main propulsion generators and motors.

4.2 Separate machinery space

4.2.1 The two means of drainage required by *Vol 2, Pt 7, Ch 1, 4.1 Metallic materials 4.1.1* are to be located in no fewer than two watertight compartments.

4.3 Machinery space — Emergency drainage

4.3.1 In addition to the dewatering suctions detailed in *Vol 2, Pt 7, Ch 2, 4.1 General*, an emergency suction is to be provided in each main machinery space. This suction is to be fitted with a screwdown non-return valve having the spindle so extended that the hand wheel is not less than 460 mm above the bottom platform.

4.3.2 The emergency suction is to be led to the largest available power pump, or an eductor which is not a dewatering unit required by *Vol 2, Pt 7, Ch 2, 4.1 General 4.1.1*. The emergency drainage suction is to be the same size as that of the pump suction branch.

4.3.3 One suction from one of the two independent means of drainage required by *Vol 2, Pt 7, Ch 2, 4.1 General 4.1.1* may be omitted on the same side of the ship where the emergency suction is fitted.

4.3.4 Emergency drainage suction valve nameplates are to be marked 'For emergency use only'.

■ *Section 5*
Size of dewatering suction pipes

5.1 Dewatering suctions

5.1.1 The diameters of dewatering suction pipes are to be selected to provide a water pumping speed of not less than 2 m/s. The internal diameter of pipes is to be not less than 50 mm.

■ *Section 6*
Drainage units on dewatering service and their connections

6.1 Number of pumping units

6.1.1 At least three power pumps for supply of water to eductors are to be provided in the machinery spaces.

6.1.2 Dewatering eductors may take suction from a suction main with branches to individual spaces or directly to individual spaces or a combination of systems.

6.2 General service pumps

6.2.1 The power pumps, required by *Vol 2, Pt 7, Ch 2, 6.1 Number of pumping units* may also be used for ballast, fire or general service duties of an intermittent nature, but not for pumping fuel or other flammable liquids. These pumps are to be immediately available for dewatering duty when required.

6.3 Capacity of pumps and educators

6.3.1 The capacity of each pump required by *Vol 2, Pt 7, Ch 2, 6.1 Number of pumping units 6.1.1* is to be sufficient to supply the eductor capacities required by *Vol 2, Pt 7, Ch 2, 6.3 Capacity of pumps and educators 6.3.2* and capable of providing water to eductors in any two compartments. Where the piping system supplying the eductors is used for other purposes, the capacity of the pumps is to be sufficient for those additional services.

6.3.2 The capacity of dewatering eductors is to be not less than required by the formulae in *Vol 2, Pt 7, Ch 2, 6.3 Capacity of pumps and educators 6.3.3* or *Vol 2, Pt 7, Ch 2, 6.3 Capacity of pumps and educators 6.3.4*.

6.3.3 Where the eductor is connected to a suction main serving more than one compartment:

$$Q = \frac{16}{10^3} L(B + D) + 15 \ \left(\mathrm{m}^3/\mathrm{h}\right)$$

where

B = greatest moulded breadth of ship, in metres

D = moulded depth to assumed damage waterline, in metres

L = length of compartments, in metres

In general, the capacity is to be not less than 75m^3/hr for ships over 100 m length.

6.3.4 Where an eductor is connected to a single suction in a machinery space or other space located below the damage waterline, the capacity is to be not less than:

$$Q = \frac{26}{10^3} C(B + D) + 15 \ \left(\mathrm{m}^3/\mathrm{h}\right)$$

where

C = length of compartment, in metres

B = and D are as defined in *Vol 2, Pt 7, Ch 2, 6.3 Capacity of pumps and educators 6.3.3*.

6.3.5 The capacity of eductors for spaces other than required by *Vol 2, Pt 7, Ch 2, 6.3 Capacity of pumps and educators 6.3.3* and *Vol 2, Pt 7, Ch 2, 6.3 Capacity of pumps and educators 6.3.4* is in general to be not less than 15 m^3/h.

6.4 Pump and eductor connections

6.4.1 The connections at the power pumps and eductors are to be such that one unit may continue in operation when the other unit is being opened up for overhaul.

6.4.2 Pump units required for Mobility systems or Ship Type systems are not to be connected to a common suction or discharge chest or pipe unless the arrangements are such that the working of any units so connected is unaffected by the other units being in operation at the same time.

Section 7
Pipe systems and their fittings

7.1 Prevention of communication between compartments

7.1.1 The arrangement of valves, cocks and their connections is to be such as to prevent the possibility of one watertight compartment being placed in communication with another or machinery spaces or other dry compartments being placed in communication with the sea or with tanks. For this purpose, screw-down non-return valves are to be provided in the following fittings:

- Bilge and dewatering valve distribution chests.
- Bilge suction hose connections, whether fitted direct to the pump or on the main suction line.
- Direct bilge and dewatering suctions and bilge pump or eductor connections to main suction lines.

7.1.2 The valves and controls required for the drainage arrangements necessary for complying with *Vol 2, Pt 7, Ch 2, 3.1 General 3.1.2* and *Vol 2, Pt 7, Ch 2, 4.1 General 4.1.2* are to be capable of being operated from the damage control deck.

7.1.3 All valves and cocks mentioned in *Vol 2, Pt 7, Ch 2, 7.1 Prevention of communication between compartments 7.1.1* and *Vol 2, Pt 7, Ch 2, 7.1 Prevention of communication between compartments 7.1.1* which can be operated from the damage control deck are to have their controls at their place of operation clearly marked and provided with means to indicate whether they are open or closed.

7.2 Isolation of bilge and dewatering systems

7.2.1 Bilge and dewatering pipes which are required for draining machinery spaces are to be entirely distinct from sea inlet pipes or from pipes which may be used for filling or emptying spaces where water or oil is carried.

7.3 Machinery space suction — Mud boxes

7.3.1 Suctions for bilge drainage and dewatering in machinery spaces and tunnels, other than emergency suctions, are to be led from easily accessible mud boxes fitted with straight tail pipes to the suction wells and having covers secured in such a manner as to permit their being expeditiously opened or closed. Strum boxes are not to be fitted to the lower ends of these tail pipes or to the emergency drainage suctions.

7.4 Compartment suctions — Strum boxes

7.4.1 The open ends of bilge and dewatering suctions in compartments outside machinery spaces and tunnels, such as cofferdams and tanks other than those permanently arranged for the carriage of fresh water, water ballast or fuel oil and for which other efficient means of pumping are provided, are to be enclosed in strum boxes having perforations of not more than 10 mm diameter, whose combined area is not less than twice that required for the suction pipe. The boxes are to be so constructed that they can be cleared without breaking any joint of the suction pipe.

7.5 Tail pipes

7.5.1 The distance between the foot of all bilge and dewatering tail pipes and the bottom of the suction well is to be adequate to allow a full flow of water and to facilitate cleaning.

7.6 Location of fittings

7.6.1 Bilge and dewatering valves, cocks and mud boxes are to be fitted at, or above, the machinery space and tunnel platforms.

7.6.2 Provision is to be made to prevent the compartment served by any bilge or dewatering suction pipe being flooded in the event of the pipe being severed, or otherwise damaged by collision or grounding in any other compartment. For this purpose, a non-return valve is to be fitted to the pipe in the compartment containing the open end.

7.6.3 Where relief valves are fitted to pumps having sea connections, these valves are to be fitted in readily visible positions above the platform. The arrangements are to be such that any discharge from the relief valves will also be readily visible.

7.7 Bilge and dewatering pipes in way of double bottom and deep tanks

7.7.1 Bilge and dewatering suction pipes are not to led through double bottom or deep tanks if it is possible avoid doing so.

7.7.2 Expansion bends, not glands, are to be fitted to these pipes within the tanks, and the pipes are to be tested, after installation, to the same pressure as the tanks through which they pass.

7.8 Non-return valves

7.8.1 Where non-return valves are fitted to the open ends of bilge or dewatering suction pipes in order to decrease the risk of flooding, they are to be of an approved type which does not offer undue obstruction to the flow of water.

■ *Section 8* Cross flooding arrangements

8.1 Cross flooding arrangements

8.1.1 Where divided deep tanks or side tanks are provided with cross flooding arrangements to limit the angle of heel after side damage, the arrangements are to be self-acting where practicable. In any case, where controls to cross flooding fittings are provided, they are to be operable from the damage control deck.

■ *Section 9* Additional requirements relating to fixed pressure water spray fire-extinguishing systems

9.1 Bilge drainage requirements

9.1.1 Where arrangements for cooling underdeck hold spaces, or fire-fighting by means of fixed spraying nozzles or by flooding of spaces with water are provided, the drainage arrangements are to be such as to be effective under all normal angles of heel and trim. The following provisions are also to be satisfied:

(a) The drainage system is to be sized to remove no less than 125 per cent of the maximum water input through fire fighting systems on each side of the ship in each fire zone.
(b) The drainage system valves are to be operable from outside the protected space. The operating position is to be in the vicinity of the extinguishing system controls where such controls are fitted.
(c) Adequately sized bilge wells are to be located at the side shell of the ship at a distance of not more than 40 m in each watertight compartment, *see also Vol 1, Pt 3, Ch 4, 8.1 General 8.1.4* and *Vol 1, Pt 4, Ch 3, 2.11 Openings in main vehicle deck*. In ships other than NS3 Ships and vessels designed to carry less than 50 embarked personnel, if it is not possible to locate the bilge wells as required, the free surface effect on the ship's stability is to be determined.

Note Normal angles of heel and trim are to be taken as:

Note 1. Ship on an even keel or has a list of not more than 5°.

Note 2. Ship on even trim or is trimmed not more than 5° for a ship up to 100 m in length. Where the length of the ship exceeds 100 m, the maximum trim may be taken as 500/L degrees where L = length of ship in metres.

Note 3. The angles of heel and trim may occur simultaneously.

9.1.2 If drainage of aircraft, vehicle or hold spaces is by gravity, the drainage is to be led directly overboard or to a closed drain tank. If led overboard the scuppers are to comply with *Vol 1, Pt 3, Ch 4, 8.1 General 8.1.3*. If led to a closed drain tank, this tank is to be located outside the machinery spaces and provided with a dedicated vent pipe leading to a safe location on the open deck. *See also Vol 1, Pt 4, Ch 3, 2.11 Openings in main vehicle deck*.

9.1.3 Drainage from a space into bilge wells in a lower space is only permitted if that space satisfies the same requirements as the space above.

9.1.4 Magazines may have specific requirements for water input for fire protection purposes and the water drainage arrangements are to take these requirements into account. *See Vol 1, Pt 4, Ch 1, 6.9 Fire protection* and *Vol 2, Pt 7, Ch 5, 10.2 Pump units*.

■ *Section 10*
Air, overflow and sounding pipes

10.1 Materials

10.1.1 Air, overflow and sounding pipes are to be made of steel or other approved material. For use of plastics pipes of approved type, *see Vol 2, Pt 7, Ch 1 Piping Design Requirements*.

10.1.2 Air, overflow and sounding pipes fitted above the weather deck are to be of steel or equivalent material.

10.2 Nameplates

10.2.1 Nameplates are to be affixed to the upper ends of all air and sounding pipes.

10.3 Air pipes

10.3.1 Air pipes are to be fitted to all tanks, cofferdams, tunnels and other compartments which are not fitted with alternative ventilation arrangements.

10.3.2 The air pipes are to be fitted at the opposite end of the tank to that which the filling pipes are placed and/or at the highest part of the tank. Where the tank top is of unusual or irregular profile, special consideration will be given to the number and position of the air pipes.

10.3.3 For tanks that are capable of being replenished when the ship is at sea, the air pipe arrangements are to be such that account is taken of ship motions during filling operations. Such arrangements are typically to incorporate at least two air pipes, situated at diagonally opposite ends of the tank. *See also Vol 2, Pt 7, Ch 3, 4.11 Filling arrangements 4.11.3* and *Vol 2, Pt 7, Ch 3, 4.18 Water compensated fuel oil tanks 4.18.10* for further requirements for fuel filling arrangements.

10.3.4 For a normally inaccessible small void compartment such as an echo sounding compartment, which is accessed from within a normally inaccessible space such as a forepeak tank, alternative air pipe arrangements to those required by *Vol 2, Pt 7, Ch 2, 10.3 Air pipes 10.3.1* may be considered. For such arrangements, a warning notice is to be located in a prominent position specifying the precautions to be taken prior to opening the manhole and entering the small void compartment. Ventilation arrangements are to be submitted to LR for approval.

10.4 Termination of air pipes

10.4.1 Air pipes to double bottom tanks, deep tanks extending to the shell plating, or tanks which can be run up from the sea are to be led to above the assumed damage waterline. Air pipes to fuel oil tanks, cofferdams and all tanks which can be pumped up are to be led to the open. For height of air pipes above deck, *see Vol 1, Pt 3, Ch 4, 7.2 Height of air pipes*.

10.4.2 Air pipes from storage tanks containing lubricating or hydraulic oil may terminate in the machinery space, provided that the open ends are so situated that issuing oil cannot come into contact with electrical equipment or heated surfaces. Air pipes from heated lubricating oil tanks are to be led to a safe position on open deck.

10.4.3 The open ends of air pipes to fuel oil tanks are to be situated where no danger will be incurred from issuing oil vapour when the tank is being filled.

10.4.4 The location and arrangement of air pipes for fuel oil service, settling and lubricating oil tanks are to be such that in the event of a broken vent pipe, this does not directly lead to the risk of ingress of sea-water or rain water.

10.5 Gauze diaphragms

10.5.1 The open ends of air pipes to fuel oil tanks are to be furnished with a wire gauze diaphragm of incorrodible material which can be readily removed for cleaning or renewal.

10.5.2 Where wire gauze diaphragms are fitted at air pipe openings, the area of the opening through the gauze is to be not less than the cross-sectional area required for the pipe. *See Vol 2, Pt 7, Ch 2, 10.8 Overflow pipes*.

10.6 Air pipe closing appliances

10.6.1 The closing appliances fitted to tank air pipes in accordance with *Vol 1, Pt 3, Ch 4, 7.2 Height of air pipes* are to be of an automatic opening type which will allow the free passage of air or liquid to prevent the tanks being subjected to a pressure or vacuum greater than that for which they are designed, and prevent the free entry of water into the tanks.

10.6.2 Air pipe closing devices are to be type tested in accordance with the test requirements in LR Test Specification Number 2. The flow characteristics of the closing device are to be determined using water. *See Vol 2, Pt 7, Ch 2, 10.8 Overflow pipes 10.8.1*.

10.6.3 Wood plugs and other devices which can be secured closed are not to be fitted at the outlets.

10.6.4 Air pipe automatic closing devices are to be so designed that they will withstand both ambient conditions, as indicated in *Vol 2, Pt 1, Ch 3, 4.4 Ambient reference conditions* and *Vol 2, Pt 1, Ch 3, 4.5 Ambient operating conditions*, and designed working conditions, and be suitable for use at inclinations up to and including ±40°.

10.6.5 Air pipe automatic closing devices are to be constructed to allow inspection of the closure and the inside of the casing as well as changing the seals.

10.6.6 Efficient ball or float seating arrangements are to be provided for the closures. Bars, cages or other devices are to be provided to prevent the ball or float from contacting the inner chamber in its normal state, and made in such a way that the ball or float is not damaged when subjected to liquid impact due to a tank being overfilled.

10.6.7 Air pipe automatic closing devices are to be self-draining.

10.6.8 The clear area through an air pipe closing device in the open position is to be at least equal to the area of the inlet.

10.6.9 In the case of air pipe closing devices of the float type, suitable guides are to be provided to ensure unobstructed operation under all working conditions of heel and trim as specified in *Vol 2, Pt 7, Ch 2, 10.6 Air pipe closing appliances 10.6.4*.

10.6.10 The maximum allowable tolerances for wall thickness of floats are not to exceed ±10 per cent of thickness.

10.6.11 The inner and the outer chambers of an automatic air pipe head are to be of a minimum thickness of 6 mm.

10.6.12 Casings of air pipe closing devices are to be of approved metallic materials, adequately protected against corrosion.

10.6.13 For galvanised steel air pipe heads, the zinc coating is to be applied by the hot method and the thickness is to be 70 to 100 microns.

10.6.14 For areas of the head susceptible to erosion (e.g. those parts directly subjected to ballast water impact when the tank is being pressed up, such as the inner chamber area above the air pipe plus an overlap of 10° or more either side), an additional harder coating should be applied. This is to be an aluminium-bearing epoxy, or other equivalent coating, applied over the zinc.

10.6.15 Closures and seats made of non-metallic materials are to be compatible with the media intended to be carried in the tank and in sea-water, and suitable for operating at ambient temperatures between –25°C and 85°C.

10.6.16 The requirements do not apply to arrangements for refuelling underway.

10.7 Size of air pipes

10.7.1 For every tank which can be filled by the ship's pumps, replenishment at sea or from shore facilities, the total cross-sectional area of the air pipes and the design of the air pipe closing devices are to be such that when the tank is overflowing at the maximum pumping capacity or maximum delivery filling rate available for the tank, it will not be subjected to a pressure greater than that for which it is designed.

10.7.2 In all cases, whether a tank is filled by ship's pumps or other means, the total cross-sectional area of the air pipes is to be not less than 25 per cent greater than the effective area of the respective filling pipe.

10.7.3 Where tanks are fitted with cross flooding connections, the air pipes are to be of adequate area for these connections.

10.7.4 Air pipes are to be not less than 50 mm bore.

10.8 Overflow pipes

10.8.1 For all tanks which can be filled by the ship's pumps or by shore pumps, overflow pipes are to be fitted where:

(a) The total cross-sectional area of the air pipe is less than that required by *Vol 2, Pt 7, Ch 2, 10.7 Size of air pipes*.
(b) The pressure head corresponding to the height of the air pipe is greater than that for which the tank is designed.

10.8.2 In the case of fuel oil and lubricating oil tanks, the overflow pipe is to be led to an overflow tank of adequate capacity or to a storage tank having a space reserved for overflow purposes. Suitable means are to be provided to indicate when overflow is occurring, or when the contents reach a predetermined level in the tanks.

10.8.3 Overflow pipes are to be self draining under normal conditions of trim.

10.8.4 Where overflow sight glasses are provided, they are to be in a vertically dropping line and designed such that the oil does not impinge on the glass. The glass is to be of heat resisting quality, adequately protected from mechanical damage and well lit.

10.9 Air and overflow systems

10.9.1 Where a combined air or overflow system is fitted, the arrangement is to be such that in the event of any one of the tanks being bilged, tanks situated in other watertight compartments of the ship cannot be flooded from the sea through combined air pipes or the overflow main. For this purpose, it will normally be necessary to lead the overflow pipe to a point close to the assumed damage waterline.

10.9.2 The arrangement is to be such that, in the event of any one of the tanks being bilged, the other tanks cannot be flooded from the sea through the combined air pipes or the overflow main.

10.9.3 Where overflow from tanks which are used for the alternative carriage of oil and water ballast are connected to an overflow system, arrangements are to be made to prevent water ballast overflowing into tanks containing oil.

10.9.4 Where a common overflow main is provided, the main is to be sized to allow any two tanks connected to that main to overflow simultaneously.

10.10 Sounding arrangements

10.10.1 Provision is to be made for sounding all tanks and the bilges of those compartments which are not at all times readily accessible. The soundings are to be taken as near the suction pipes as practicable.

10.10.2 Bilges of compartments which are not at all times readily accessible are to be provided with sounding pipes.

10.10.3 Where fitted, sounding pipes are to be as straight as practicable;, and if curved to suit the structure of the ship, the curvature must be sufficiently easy to permit the ready passage of the sounding rod or chain.

10.10.4 Sounding devices of approved type may be used in lieu of sounding pipes for sounding tanks. These devices are to be tested, after fitting on board, to the satisfaction of the Surveyors.

10.10.5 Where gauge glasses are used for indicating the level of liquid in tanks containing lubricating oil, fuel oil or other flammable liquid, the glasses are to be of the flat type of heat-resisting quality, adequately protected from mechanical damage, and fitted with self-closing valves at the lower ends and at the top ends if these are connected to the tanks below the maximum liquid level.

10.10.6 If means of sounding, other than a sounding pipe, are fitted in any ship for indicating the level of liquid in tanks containing fuel oil, lubricating oil or other flammable liquid, failure of such means or over filling of the tank should not result in the release of tank contents.

10.10.7 For a normally inaccessible small void compartment, such as an echo sounding compartment, which is accessed from within a normally inaccessible space such as a forepeak tank, alternative sounding arrangements to those required by *Vol 2, Pt 7, Ch 2, 10.10 Sounding arrangements 10.10.1* may be considered. For such arrangements, a warning notice is to be located in a prominent position specifying precautions to be taken prior to opening the manhole of the small void compartment. Means are to be provided to indicate flooding of the compartment without opening, such as fitting indicator plugs to the manhole. Sounding arrangements are to be submitted to LR for approval.

10.11 Termination of sounding pipes

10.11.1 Sounding pipes are to be led to positions above the assumed damage waterline which are at all times accessible and, in the case of fuel oil tanks, refuelling oil tanks, lubricating oil tanks and tanks containing other flammable oils, the sounding pipes are to be led to safe positions on the open deck.

10.11.2 For closing requirements, *see also Vol 1, Pt 3, Ch 4, 7.2 Height of air pipes*.

10.12 Short sounding pipes

10.12.1 In machinery spaces and tunnels, in circumstances where it is not practicable to extend the sounding pipes as mentioned in *Vol 2, Pt 7, Ch 2, 10.11 Termination of sounding pipes*, short sounding pipes extending to well lighted readily accessible positions above the platform may be fitted to double bottom tanks. Where such pipes serve tanks containing fuel oil or other flammable liquid, an additional sounding device of approved type is to be fitted. An additional sounding device is not required for lubricating oil tanks. Any proposal to terminate in the machinery space, sounding pipes to tanks, other than double bottom tanks, will be the subject of special consideration.

10.12.2 Short sounding pipes to fuel oil and lubricating oil tanks, and other flammable oil tanks (flash point not less than 60°C) are to be fitted with cocks having parallel plugs with permanently attached handles, so loaded that, on being released, they automatically close the cocks. In addition, a small diameter self-closing test cock is to be fitted below the cock mentioned above in order to ensure that the sounding pipe is not under a pressure of oil before opening up the sounding cock. Provision is to be made to ensure that discharge of oil through this test cock does not present an ignition hazard. An additional small diameter self-closing test cock is not required for lubricating oil tanks.

10.12.3 As a further precaution against fire, such sounding pipes are to be located in positions as far removed as possible from any heated surface or electrical equipment and, where necessary, effective shielding is to be provided in way of such surfaces and/or equipment.

10.12.4 In ships that are required to be provided with a double bottom, short sounding pipes, where fitted to double bottom tanks, are in all cases to be provided with self-closing cocks as described in *Vol 2, Pt 7, Ch 2, 10.12 Short sounding pipes 10.12.2*.

10.12.5 Where a double bottom is not required to be fitted, short sounding pipes to tanks other than oil tanks are to be fitted with shut-off cocks or with screw caps attached to the pipes by chains.

10.13 Elbow sounding pipes

10.13.1 Elbow sounding pipes are not to be used for deep tanks unless the elbows and pipes are situated within closed cofferdams or within tanks containing similar liquids. They may, however, be fitted to other tanks and may be used for sounding bilges, provided that it is not practicable to lead them direct to the tanks or compartments, and subject to any sub-division and damage stability requirements that may apply, *see Vol 2, Pt 7, Ch 2, 1.3 Prevention of progressive flooding in damage condition 1.3.1*.

10.13.2 The elbows are to be of heavy construction and adequately supported.

10.14 Striking plates

10.14.1 Striking plates of adequate thickness and size are to be fitted under open ended sounding pipes.

10.14.2 Where slotted sounding pipes having closed ends are employed, the closing plugs are to be of substantial construction.

10.15 Size of sounding pipes

10.15.1 Sounding pipes are to be not less than 32 mm bore.

10.15.2 All sounding pipes, whether for compartments or tanks, which pass through refrigerated spaces or the insulation thereof, in which the temperatures contemplated are 0°C or below, are to be not less than 65 mm bore.

10.16

10.16.1 For ‘Ice Class’ requirements, *see Vol 3, Pt 1, Ch 1 Ice Navigation - First-Year Ice Conditions*.

For control engineering equipment, *see Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*.

For requirements relating to scuppers and sanitary discharges, *see Vol 1, Pt 3, Ch 4 Closing Arrangements and Outfit*.

Section 11
Ballast System

11.1 General

11.1.1 Any deck and bulkhead penetrations shall meet the requirements of *Vol 2, Pt 7, Ch 2, 1 General requirements*.

11.1.2 There shall be no transfer of ballast water from hazardous areas to non-hazardous areas.

11.1.3 Where transfer of ballast water from non-hazardous to hazardous areas is required, connection between the areas is to be non-permanent. Such non-permanent connections are to be in accordance with the Rules for Ships, *Pt 5, Ch 15, 2 Piping systems for bilge, ballast, fuel oil, etc.*.

11.2 Standby arrangements for ballast pumping

11.2.1 Where ballasting/de-ballasting is required for ship operation, standby ballast pumping arrangements are to be provided, *see* also *Vol 2, Pt 7, Ch 2, 6.2 General service pumps 6.2.1*.

11.3 Integrated cargo and ballast systems

11.3.1 Controls used for stopping the cargo system, including normal controls, safety shutdowns and Emergency Stop Functions as defined by *Vol 2, Pt 9, Ch 1, 1.3 Definitions*, shall not stop operation of the ballast system. All control systems shall, as a minimum, meet the applicable requirements of *Vol 2, Pt 9, Ch 1, 2.7 Electrical supplies to systems fulfilling military requirement*.

11.3.2 Where **UMS**, **CCS** or **ICC** notations are applied, the control systems shall also meet the requirements of *Vol 2, Pt 9, Ch 1, 4 Unattended machinery space(s) — UMS notation*, *Vol 2, Pt 9, Ch 1, 5 Machinery operated from a centralised control station – CCS notation* and *Vol 2, Pt 9, Ch 1, 6 Integrated computer control - ICC notation* respectively and the further applicable requirements of *Vol 2, Pt 9, Ch 11, 1 Testing and trials*.

11.4 Ballast water treatment system installations

11.4.1 Failure of a ballast water treatment system shall not impair or restrict ballasting or de-ballasting operations.

11.4.2 Failure of a ballast water treatment system shall not impair or restrict any other Mobility and/or Ship Type piping system, as defined by Ch 1,2.2.1, or any other Mobility system or Ship Type system as defined by *Vol 2, Pt 1, Ch 1, 3.1 Categories 3.1.5*.

11.4.3 Ballast water treatment systems are to be installed with a by-pass arrangement, designed to ensure that the treatment system can be efficiently isolated from the ballast water system without impairing ballast water flow.

11.4.4 All piping and components as defined in*Vol 2, Pt 7, Ch 1, 2.2 Definitions 2.2.3* and forming part of the ballast water treatment system shall meet the requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements*.

11.4.5 All electrical equipment forming part of ballast water treatment units shall meet the applicable requirements of *Vol 2, Pt 9 Electrotechnical Systems*. All control equipment forming part of the ballast water treatment units shall meet the applicable requirements of Pt 9. Hazardous areas associated with ballast water treatment system installations are to be determined in accordance with the requirements of *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*.

■ *Section 1* General requirements

1.1 Application

1.1.1 This Chapter covers the requirements for machinery piping systems installed in naval ships for the continuous and safe operation of main and auxiliary machinery and engineering systems.

1.1.2 In addition to the requirements detailed in this Chapter, the requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements*, *Vol 2, Pt 7, Ch 2 Ship Piping System*, Sections 1 and 2 are to be complied with where applicable.

1.1.3 The requirements of *Vol 2, Pt 2, Ch 1, 7 Starting arrangements* are to be complied with for compressed air systems for starting of oil engines.

1.1.4 The requirements of *Vol 2, Pt 7, Ch 2, 3 Drainage of compartments, other than machinery spaces* are also to be complied with, so far as they are applicable, for the drainage of tanks, oily bilges and cofferdams, etc.

1.1.5 The requirements of *Vol 2, Pt 7, Ch 3, 2 Fuel oil - General requirements* and *Vol 2, Pt 7, Ch 3, 4 Fuel oil pumps, pipes, fittings, tanks, etc.* are to be complied with, as far as they are applicable, for all flammable liquids.

1.1.6 The control and monitoring requirements for prime movers, transmission systems, propulsion devices, steering systems and boilers in *Vol 2, Pt 2 Prime Movers*, *Vol 2, Pt 3 Transmission Systems*, *Vol 2, Pt 4 Propulsion Devices*, *Vol 2, Pt 6 Steering Systems* and *Vol 2, Pt 8 Pressure Plant* are also to be complied with where applicable.

1.1.7 Where reference is made to main auxiliary engines, the requirements are also applicable to main and auxiliary gas turbines.

1.2 Documentation required for design review

1.2.1 Three copies of the following plans (in diagrammatic form) and a System Design Description containing the additional information are to be submitted for approval. Additional plans should not be submitted unless the arrangements are of novel or special character affecting classification:

- Arrangements of fuel oil bunkering, storage and transfer.
- Arrangements of fuel oil piping in connection with oil burning installations.
- Arrangements of fuel oil burning units for boilers and thermal fluid heaters.

- Arrangements of any gas burning installations.
- Arrangement of boiler feed system.
- Arrangements of thermal fluid circulation systems.
- Arrangement of compressed air systems for main and auxiliary services.
- Arrangements of lubricating oil systems.
- Arrangements of flammable liquids used for control and heating systems.
- Arrangements of Mobility systems or Ship Type systems for power transmission.
- Arrangements of non-flammable liquids used for power transmission and control systems in Mobility category and Ship Type category engineering systems.
- Arrangements of cooling water systems for main and auxiliary purposes.
- fuel oil settling service and other fuel oil tanks not forming part of the ship's structure.
- Arrangements of steam systems for main and auxiliary services.
- Arrangements of incinerator systems.
- Arrangements of air intakes and exhaust gas piping for main and auxiliary machinery.
- Description of fuel oils with statement of minimum flash point (closed-cup test).
- Arrangements and dimensions of all steam and thermal fluid pipes where the design pressure or temperature exceeds 16,0 bar (16,3 kgf/cm^2) or 300°C, respectively, and the outside diameter exceeds 76,1 mm, with details of flanges, bolts and weld attachments, and particulars of the material of pipes, flanges, bolts and electrodes.
- Operating manuals and maintenance instructions are to be provided on board and submitted for information where requested by LR. The manuals are to include particulars, description, operating instructions and maintenance instructions for all systems.

1.2.2 *See Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems* for details of plans to be submitted for control, monitoring and alarm systems.

■ *Section 2* **Fuel oil - General requirements**

2.1 Flash point

2.1.1 The flash point (closed-cup test) of fuel oil for use in naval ships classed for unrestricted service is, in general, to be not less than 60ºC.

2.1.2 The use of fuel having a lower flash point than specified in *Vol 2, Pt 7, Ch 3, 2.1 Flash point 2.1.1* may be permitted provided that such fuel is not stored in any machinery space and the arrangements for the complete installation are specially approved.

2.1.3 Fuel oil in storage tanks is not to be heated to a temperature exceeding 10ºC below its flash point. Higher temperatures will be considered for fuel oil stored in settling and service tanks where:

(a) The tanks are vented to a safe position outside the engine room and, as in the case of all fuel oil tanks, the ends of the ventilation pipes are fitted with gauze diaphragms.
(b) Openings in the drainage systems of tanks containing heated fuel oil are located in spaces where no accumulation of oil vapours at temperatures close to the flash point can occur.
(c) The length of vent pipes from such tanks and/or a cooling device is sufficient for cooling oil vapours to below 60°C, or the outlet of the vent pipes is located at least 3 m from sources of ignition.
(d) There is no source of ignition in the vicinity of openings in the drainage systems.
(e) There are no openings from the vapour space of the fuel tanks into machinery spaces other than bolted sealed manhole covers.
(f) Enclosed spaces are not located directly over such fuel tanks, except for vented cofferdams.
(g) Electrical equipment is not fitted in the vapour space of tanks unless it meets the requirements of *Vol 2, Pt 9, Ch 5, 4.1 General 4.1.1* for electrical equipment in zone 0 explosive atmospheres.

2.1.4 The temperature of any heating medium is not to exceed 220ºC.

2.2 Special fuels

2.2.1 When it is desired to carry a quantity of fuel having a flash point below 60ºC for special services, e.g. aviation spirit for use in helicopters or vehicles, full particulars of the proposed arrangements are to be submitted for consideration, *see Vol 2, Pt 7, Ch 4 Aircraft/Helicopter/Vehicle Fuel Piping and Arrangements*.

2.3 Fuel oil sampling

2.3.1 Sampling points are to be provided at locations within the fuel oil system that enable samples of fuel oil to be taken in a safe manner.

2.3.2 The position of a sampling point is to be such that the sample of the fuel oil is representative of the fuel oil quality at that location within the system.

Note Samples taken from sounding pipes are not considered to be representative of the tank's contents.

2.3.3 The sampling arrangements within the machinery space are to be capable of safely providing samples when machinery is running and are to be provided with isolating valves and cocks of the self-closing type. The sampling points are to be located in positions as far removed as possible from any heated surface or electrical equipment such as to preclude impingement of fuel oil onto such surfaces on equipment under all operating conditions, *see Vol 2, Pt 1, Ch 3, 4.6 Inclination of ship*.

2.4 Ventilation

2.4.1 The spaces in which the fuel oil burning appliances and the fuel oil settling and service tanks are fitted are to be well ventilated and easy of access.

2.5 Boiler insulation and air circulation in boiler room

2.5.1 The boilers are to be suitably lagged. The clearance spaces between the boilers and tops of the double bottom tanks, and between the boilers and the sides of the storage tanks in which fuel oil and refuelling oil is carried, are to be adequate for the free circulation of the air necessary to keep the temperature of the stored oil sufficiently below its flash point.

2.5.2 Where water tube boilers are installed, there is to be a space of at least 760 mm between the tank top and the underside of the pans forming the bottom of the combustion spaces.

2.5.3 Smoke-box doors are to be shielded and well fitting, and the uptake joints made gastight. Where the surface temperature of the uptakes may exceed 220ºC, they are to be efficiently lagged to minimise the risk of fire and to prevent damage by heat. Where lagging covering the uptakes, including flanges, is oil-absorbing or may permit penetration of oil, the lagging is to be encased in sheet metal or equivalent. In locations where the Surveyor is satisfied that oil impingement could not occur, the lagging need not be encased.

2.6 Funnel dampers

2.6.1 Dampers which are capable of completely closing the gas passages are not to be fitted to inner funnels of ships equipped for burning fuel oil only.

2.7 Heating arrangements

2.7.1 Where steam is used for heating fuel oil or lubricating oil, in bunkers, tanks, heaters or separators, the exhaust drains are to discharge the condensate into an observation tank in a well lighted and accessible position where it can be readily seen whether or not it is free from oil.

2.7.2 Where hot water is used for heating, means are to be provided for detecting the presence of oil in the return lines from the heating coils.

2.7.3 Where it is proposed to use any heating medium other than steam or hot water, full particulars of the proposed arrangements are to be submitted for special consideration.

2.7.4 The heating pipes in contact with oil are to be of iron, steel, approved aluminium alloy or approved copper alloy, and, after being fitted on board, are to be tested by hydraulic pressure in accordance with the requirements of *Vol 2, Pt 7, Ch 1, 16.1 Hydraulic tests before installation on board*.

2.7.5 Where electric heating elements are fitted, means are to be provided to ensure that all elements are submerged at all times when electric current is flowing and that their surface temperature cannot exceed 220ºC, *see Vol 2, Pt 7, Ch 3, 9.5 Miscellaneous machnery*.

2.8 Temperature indication

2.8.1 Tanks and heaters in which oil is heated are to be provided with suitable means for ascertaining the temperature of the oil. Where thermometers or temperature sensing devices are not fitted in blind pockets, a warning notice, in raised letters, is to be affixed adjacent to the fittings stating 'Do not remove unless tank/heater is drained'.

2.8.2 Controls are to be fitted to limit oil temperatures in oil storage and service tanks in accordance with *Vol 2, Pt 7, Ch 3, 2.1 Flash point 2.1.4* and in oil heaters to the maximum approved operating temperature, *see Vol 2, Pt 7, Ch 3, 9.5 Miscellaneous machnery*.

2.9 Precautions against fire

2.9.1 As far as practicable, fuel oil tanks are to be part of the ship's structure and are to be located outside machinery spaces of Category A. Where fuel oil tanks, other than double bottom tanks, are necessarily located adjacent to or within machinery spaces of Category A, at least one of their vertical sides is to be joined to the machinery space boundaries. Such tanks are also preferably to have a common boundary with the double bottom tanks, and the area of a tank boundary common with the machinery spaces is to be kept to a minimum. Where such tanks are situated within the boundaries of machinery spaces of Category A they are not to contain fuel oil having a flash point of less than 60°C.

2.9.2 In general, the use of free-standing fuel oil tanks is to be avoided. Such tanks are prohibited in Category A machinery spaces on ships carrying more than 50 embarked personnel. Where free-standing tanks are permitted, they are to be placed in an oil-tight spill tray of ample size having a suitable drain pipe leading to a suitably sized drain tank.

2.9.3 Tanks containing flammable liquids are not to be situated above or within one metre of engines, boilers, exhausts/ uptakes or other highly heated surfaces.

2.9.4 Fuel oil pipes are not to be installed above or near high temperature equipment. Fuel oil pipes should also be installed and screened or otherwise suitably protected to avoid oil spray or oil leakages onto hot surfaces, into machinery air intakes, or other sources of ignition such as electrical equipment. Pipe joints are to be kept to a minimum, and where provided are to be of a type acceptable to Lloyd's Register (hereinafter referred to as 'LR'). Pipes are to be led in well lit and readily visible positions, *see also Vol 2, Pt 7, Ch 2, 2.8 Miscellaneous requirements 2.8.2*.

2.9.5 Pumps, heaters, filters and strainers and heaters are to be located to avoid oil spray or oil leakages onto hot surfaces or other sources of ignition, or onto rotating machinery parts. Where necessary, shielding is to be provided and the arrangements are to allow easy access for routine maintenance. The design of filters and strainers is to be such as to avoid the possibility of them being opened inadvertently when under pressure. This may be achieved by either mechanically preventing the pressurised filter from being opened or by providing pressure gauges which clearly indicate which filter is under pressure. In either case, suitable means for pressure release are to be provided, with drain pipes led to a safe location.

2.9.6 The arrangement and location of short sounding pipes to oil tanks are to be in accordance with *Vol 2, Pt 7, Ch 2, 10.12 Short sounding pipes*. For alternative sounding arrangements, *see Vol 2, Pt 7, Ch 2, 10.10 Sounding arrangements*.

2.9.7 Water service pipes and hoses are to be fitted in order that the floor plates and tank top or shell plating in way of boilers, fuel oil apparatus or deep storage tanks in the engine and boiler spaces can at any time be flushed with sea-water.

2.9.8 So far as is practicable, the use of wood is to be avoided in the engine rooms, boiler rooms and tunnels of ships burning fuel oil.

2.9.9 Drip trays are to be fitted at the furnace mouths to intercept oil escaping from the burners, and under all other fuel oil appliances which are required to be opened up frequently for cleaning or adjustment.

2.9.10 Oil-tight drip trays of ample size having suitable drainage arrangements are to be provided at pipes, pumps, valves and other fittings where there is a possibility of leakage. Valves should be located in well lighted and readily visible positions. Drip trays will not be required where pumps, valves and other fittings are placed in special compartments either inside or outside the machinery space with approved overall drainage arrangements or for valves which are so positioned that any leakage will drain directly into the bilges, *see Vol 2, Pt 7, Ch 3, 2.9 Precautions against fire 2.9.4*.

2.9.11 Where drainage arrangements are provided from collected leakages, they are to be led to a suitable drain tank not forming part of the overflow system.

2.9.12 Separate fuel oil tanks are to be placed in an oil tight spill tray of ample size having drainage arrangements leading to a drain tank of suitable size.

2.9.13 Where level switches are used below the tank top, they are to be contained in a steel enclosure or other enclosures which provide an equivalent protection against fire.

2.10 Fuel oil contamination

2.10.1 The materials and/or their surface treatment used for the storage and distribution of fuel oil are to be selected such that they do not introduce contamination or modify the properties of the fuel. The use of copper or zinc compounds in fuel oil piping systems where they may come into contact with the fuel is not permitted except for small diameter pipes in low pressure systems, *see Vol 2, Pt 7, Ch 3, 4.6 Low pressure pipes 4.6.1*.

2.10.2 Corrosion resistant materials are to be used for fuel oil pipes between the treatment system required by *Vol 2, Pt 7, Ch 3, 3.9 Fuel oil treatment for supply to diesel engines and gas turbines 3.9.3* and the combustion system.

2.10.3 For prevention of ingress of water into fuel oil tanks via air pipes, *see Vol 2, Pt 7, Ch 2, 10.4 Termination of air pipes 10.4.4*.

2.10.4 The piping arrangements for fuel oil are to be separate and distinct from those intended for lubricating oil systems to prevent contamination of fuel oil by lubricating oil.

2.10.5 The piping arrangements for gas oil, distillate and diesel grades are to be separate and distinct from those intended for residual grades, up to the service tanks required by *Vol 2, Pt 7, Ch 3, 4.17 Fuel oil service tanks*, to prevent cross-contamination. Cross-connection is permitted between separate arrangements in the event of failure of a designated item of equipment.

2.11 Tanks and cofferdams

2.11.1 Tanks containing fuel oil are to be separated from vehicle spaces, crew, embarked personnel, passenger and baggage compartments by a gastight and watertight boundary or a cofferdam which is suitably ventilated and drained.

■ *Section 3* Fuel oil burning arrangements

3.1 Oil burning units

3.1.1 All oil burning equipment is to be capable of operating at defined power/rating levels where specified. Confirmation by the manufacturer of this capability is to be provided to LR, including the specified power/rating parameters, and operating and maintenance regimes. *See also Vol 2, Pt 1, Ch 3, 4.1 Availability for operation 4.1.2*.

3.1.2 Where steam is required for the main propelling engines, or where steam or thermal fluid is required for auxiliary machinery for Mobility systems or Ship Type systems, or for heating of heavy fuel oil and is generated by burning fuel oil under pressure, there are to be not less than two oil burning units. For auxiliary boilers and thermal oil heaters, a single oil burning unit may be accepted, provided that alternative means, such as an exhaust gas heated boiler or heater, are available for supplying steam or thermal fluid for Mobility systems or Ship Type systems. Where the oil burning unit is not of the monobloc type (i.e. separate register and oil supply unit) each oil burning unit is to comprise a pressure pump, suction filter, discharge filter and, when required, a heater.

3.1.3 Where steam or thermal fluid is required to provide essential services, the number, arrangement and capacity of oil burning units is to be capable of supplying sufficient fuel to allow the steam or thermal fluid required to provide essential services to be generated with any one unit out of action.

3.1.4 Unit pressure pumps are to be entirely separate from the feed, bilge or ballast systems.

3.1.5 In dual fuel oil burning systems for boilers which are primarily designed for operation with residual fuel oil grades, arrangements are to be such that atomising steam cannot be used in combination with distillate fuel oil grades.

3.1.6 In all dual fuel oil burning systems for boilers, the manufacturer of the combustion equipment is to ensure that the full system, including control and monitoring systems, is capable of continuous operation in all conditions for each fuel grade.

3.1.7 Whenever the fuel oil burning units are stopped, shut-off arrangements for fuel oil to the units are to be provided as follows:

(a) If the supply fuel oil is under pressure during shut-off to oil burning units, duplicated shut-off valves in series are to be fitted. Cocks are to be fitted to allow manual testing for leakage from each of the valves in the installed condition, they are to be capable of being locked in the closed position and any discharges are to be led to a safe position to ensure that discharge of oil through the test cocks does not present an ignition hazard.

(b) If arrangements are such that fuel oil pressure is released through drainage during fuel oil shut-off to oil burning units, a single shut-off device may be accepted subject to approval by LR.

3.1.8 When combined air and fuel/steam/air combustion systems are used for multiple boiler installations, they are to be such that single boiler operation will not be adversely affected by the operation of another boiler system at any time.

3.1.9 Arrangements are to be such that furnace prepurging is completed prior to any burner ignition sequence. The purge time is to be based on a minimum of 4 air changes of the combustion chamber, furnace and uptake spaces. The purge timing is to take account of the air flow rate and the sequence is not to commence until all air registers and dampers as applicable are fully open and the forced draft fans are operating.

3.1.10 The effect of multiple light-off failures is to be assessed and the need to lock out further ignition sequences established.

3.1.11 Means are to be provided so that, in the event of flame failure, the fuel oil supply to the burner(s) is shut off automatically, and an alarm is given, *see Vol 2, Pt 7, Ch 3, 9.3 Thermal fluid heaters* and *Vol 2, Pt 7, Ch 3, 9.4 Incinerators*, and *Vol 2, Pt 8, Ch 1, 18 Control and monitoring* as applicable.

3.1.12 It is to be demonstrated to the Surveyor's satisfaction during trials that burner shut-off times due to flame failure comply with the following requirements and details of the procedures and means used to set this time interval are to be submitted for consideration:

(a) The time interval at burner start up between the burner fuel oil valve(s) being opened and then closed in the event of flame failure is to be long enough to allow a stable flame to be established and detected under normal operational circumstances but is to be set to minimise the quantity of fuel oil delivered to the furnace and the possibility of subsequent damage as a result of unintended ignition.
(b) The time interval between flame failure detection and closing of burner fuel oil valve(s) is to be long enough to prevent shutdown due to incorrect detection of a flame failure under normal operational circumstances but is to be set to minimise the quantity of unburned fuel oil delivered to the furnace and the possibility of subsequent damage as a result of unintended ignition.

3.1.13 A warning notice is to be fitted in a prominent position at every oil burning unit local manual control station which specifies that burners operated with manual or local overrides in use are only to be ignited after sufficient purging of the furnace and of any additional precautions required when operating in this condition.

3.2 Gravity feed

3.2.1 In systems where oil is fed to the burners by gravity, duplex filters are to be fitted in the supply pipeline to the burners and so arranged that one filter can be opened up when the other is in use.

3.3 Starting-up point

3.3.1 A starting-up fuel oil unit, including an auxiliary heater and hand pump, or other suitable starting-up device, which does not require power from shore, is to be provided.

3.3.2 Alternatively, where auxiliary machinery requiring compressed air or electric power is used to bring the boiler plant into operation, the arrangements for starting such machinery are to comply with *Vol 2, Pt 7, Ch 3, 12.11 Dead ship condition starting arrangements*.

3.4 Steam connections to burners

3.4.1 Where burners are provided with steam purging and/or atomising connections, the arrangements are to be such that oil cannot find its way into the steam system in the event of valve leakage.

3.5 Burner arrangements

3.5.1 The burner arrangements are to be such that a burner cannot be withdrawn unless the oil supply to that burner is shut off, and that the oil cannot be turned on unless the burner has been correctly coupled to the supply line.

3.6 Quick-closing valve

3.6.1 A quick-closing master valve is to be fitted to the oil supply to each boiler manifold, suitably located so that the valve can be readily operated in an emergency, either directly or by means of remote control, having regard to the machinery arrangements and location of controls.

3.7 Spill arrangements

3.7.1 Provision is to be made, by suitable non-return arrangements, to prevent oil from spill systems being returned to the burners when the oil supply to these burners has been shut off.

3.8 Alternately fired furnaces

3.8.1 For alternately fired furnaces of boilers using exhaust gases and fuel oil, the exhaust gas inlet pipe is to be provided with an isolating device and interlocking arrangements whereby fuel oil can only be supplied to the burners when the isolating device is closed to the boiler.

3.9 Fuel oil treatment for supply to diesel engines and gas turbines

3.9.1 Suitable fuel treatment plant that may include filtration, centrifuging and/or coalescing is to be provided to reduce the level of water and particulate contamination of the fuel oil to within the engine or gas turbine manufacturer's limits for inlet to the combustion system. The capacity and arrangements of the treatment plant is to be suitable for ensuring availability of treated fuel oil for the maximum continuous rating of the propulsion and electrical generating plant.

3.9.2 Two or more treatment systems are to be provided such that failure of one system will not render the other system(s) inoperative. Arrangements are to ensure that the failure of a treatment system will not interrupt the supply of clean fuel oil to diesel engines or gas turbines used for propulsion and electrical generator purposes. Any treatment equipment in the system is to be capable of being cleaned without interrupting the flow of treated fuel to supply the combustion system.

3.9.3 Where centrifuges are used for fuel oil treatment they are to be type tested in accordance with a standard acceptable to LR and are to be installed on board in accordance with the manufacturer's recommendations. The fuel grades, flow rates and any heating arrangements on board are to be consistent with the specification for type tested centrifuge.

3.9.4 Where heating of the fuel oil is required for the efficient functioning of the fuel oil treatment plant, a minimum of two heating units is to be provided. Each heating unit is to be of sufficient capacity to raise and maintain the required temperature of the fuel oil for the required delivery flow rate.

3.9.5 Heating units may be in circuit with separate treatment systems or provided with connections such that any heating unit can be connected to any treatment system.

3.9.6 Where heating of the fuel oil is required for combustion, not less than two pre-heaters are to be provided, each with sufficient capacity to raise the temperature of the fuel to provide a viscosity suitable for combustion.

3.9.7 Filters and/or coalescers are to be fitted in the fuel oil supply lines to each diesel engine and gas turbine to ensure that only suitably filtered oil is fed to the combustion system. The arrangements are to be such that any unit can be cleaned without interrupting the supply of filtered oil to the combustion system.

3.10 Booster pumps

3.10.1 Where a fuel oil booster pump is fitted, which is essential to the operation of the main engine, a standby pump is to be provided.

3.10.2 The standby pump is to be connected ready for immediate use but where two or more main engines are fitted, each with its own pump, a complete spare pump may be accepted provided that it is readily accessible and can easily be installed.

3.11 Booster pumps when operating in emissions control areas

3.11.1 Ships intending to use Heavy Fuel Oil (HFO) or Marine Diesel Oil (MDO) when operating outside emissions control areas and marine fuels with a sulphur content not exceeding 0,1 per cent m/m and minimum viscosity of 2 cSt when operating inside emission control areas are to meet the requirements of *Vol 2, Pt 7, Ch 3, 3.11 Booster pumps when operating in emissions control areas 3.11.2* or *Vol 2, Pt 7, Ch 3, 3.11 Booster pumps when operating in emissions control areas 3.11.3*.

3.11.2 The booster pumps which are fitted in compliance with *Vol 2, Pt 7, Ch 3, 3.10 Booster pumps* are acceptable for use in emissions control areas where these pumps are each suitable for marine fuels with a sulphur content not exceeding 0,1 per cent m/m and minimum viscosity of 2 cSt operation at the required capacity for normal operation of propulsion machinery.

3.11.3 When the booster pumps which are fitted in compliance with *Vol 2, Pt 7, Ch 3, 3.11 Booster pumps when operating in emissions control areas 3.11.2*, and one pump alone is not capable of delivering marine fuels with a sulphur content not exceeding 0,1 per cent m/m and minimum viscosity of 2 cSt at the required capacity, two booster pumps may operate in parallel to achieve the required capacity for normal operation of propulsion machinery. In this case, one additional fuel oil supply pump is to be

provided. The additional booster pump shall, when operating in parallel with one of the booster pumps in 3.10, be suitable for and capable of delivering marine fuels with a sulphur content not exceeding 0,1 per cent m/m and minimum viscosity of 2 cSt at the required capacity for normal operation of the propulsion machinery.

3.12 Fuel valve cooling pumps

3.12.1 Where pumps are provided for fuel valve cooling, the arrangements are to be in accordance with *Vol 2, Pt 7, Ch 3, 3.10 Booster pumps*.

■ *Section 4* Fuel oil pumps, pipes, fittings, tanks, etc.

4.1 Transfer pumps

4.1.1 Where a power driven pump is necessary for transferring fuel oil, a standby pump is to be provided and connected ready for use, or, alternatively, emergency connections may be made to one of the unit pumps or to another suitable power driven pump.

4.2 Control of pumps

4.2.1 The power supply to all independently driven fuel oil transfer and pressure pumps is to be capable of being stopped from a position outside the space which will always be accessible in the event of fire occurring in the compartment in which they are situated, as well as from the compartment itself.

4.3 Relief valves on pumps

4.3.1 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be in closed circuit, i.e. arranged to discharge back to the suction side of the pump and effectively to limit the pump discharge pressure to the design pressure of the system.

4.4 Pump connections

4.4.1 Valves or cocks are to be interposed between the pumps and the suction and discharge pipes, in order that any pump may be shut off for opening up and overhauling.

4.5 Pipes conveying heated oil

4.5.1 Pipes conveying oil under pressure are to be of seamless steel or other approved material having flanged or welded joints, and are to be placed in sight above the platform in well lighted and readily accessible parts of the machinery spaces. The number of flanged joints is to be kept to a minimum.

4.5.2 Where pipe systems convey heated oil under pressure and include flanged joints, the flanges and joints are to be suitable for a design pressure of at least 13,7 bar (14 kgf/cm^2) or the design pressure, whichever is the greater and a design temperature of 150°C or the design temperature whichever is the greater. They are to comply with a relevant and acceptable National or International Standard, and the requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements* at the defined temperature and pressure. Materials for the pipes, flanges and gaskets are to be suitable for the conveyed medium at the defined temperature and pressure.

4.5.3 The short joining lengths of pipes to the burners from the control valves at the boiler may have cone unions, provided these are of specially robust construction.

4.5.4 Flexible hoses of approved material and design may be used for the burner pipes, provided that spare lengths, complete with couplings, are carried on board.

4.5.5 For requirements relating to flexible hoses, *see Vol 2, Pt 7, Ch 1, 13 Flexible hoses*.

4.6 Low pressure pipes

4.6.1 Transfer, suction and other low pressure oil pipes and all pipes passing through oil storage tanks are to be made of steel, having flanged joints suitable for a working pressure of not less than 6,9 bar. The flanges are to be machined and the jointing

material is to be impervious to oil. Where the pipes are 25 mm bore or less, they may be of seamless copper or copper alloy, except those which pass through oil storage tanks. Oil pipes within the engine and boiler spaces are to be fitted where they can be readily inspected and repaired.

4.6.2 For requirements regarding bilge and dewatering pipes in way of double bottom tanks and deep tanks, *see Vol 2, Pt 7, Ch 2, 7.7 Bilge and dewatering pipes in way of double bottom and deep tanks*.

4.7 Valves and cocks

4.7.1 Valves, cocks and their pipe connections are to be so arranged that oil cannot be admitted into tanks which are not structurally suitable for the carriage of oil or into tanks which can be used for the carriage of fresh water.

4.7.2 All valves and cocks forming part of the fuel oil installation are to be capable of being controlled from readily accessible positions which, in the engine and boiler spaces, are to be above the working platform. *See also Vol 2, Pt 7, Ch 2, 2.3 Valves - Installation and control*.

4.7.3 Every fuel oil suction pipe from a double bottom tank is to be fitted with a valve or cock.

4.8 Valves on deep tanks and their control arrangements

4.8.1 Every fuel oil suction pipe from a storage, settling and daily service tank situated above the double bottom, and every fuel oil levelling pipe within the boiler room or engine room, is to be fitted with a valve or cock secured to the tank.

4.8.2 The valves and cocks mentioned in *Vol 2, Pt 7, Ch 3, 4.8 Valves on deep tanks and their control arrangements 4.8.1* are to be capable of being closed locally and from positions outside these spaces. The remote controls are to be accessible in the event of fire occurring in the deep tank's space. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions.

4.8.3 The control for remote operation of the valve on the emergency generator fuel tank is to be in a separate location from the controls for the remote operation of other valves for tanks located in machinery spaces.

4.8.4 In the case of tanks of less than 500 litres capacity consideration will be given to the omission of remote controls.

4.8.5 Every fuel oil suction pipe which is led into the engine and boiler spaces, from a tank situated above the double bottom outside these spaces, is to be fitted in the machinery space with a valve controlled as in *Vol 2, Pt 7, Ch 3, 4.8 Valves on deep tanks and their control arrangements 4.8.2*, except where the valve on the tank is already capable of being closed from an accessible position on the damage control deck.

4.8.6 Where the filling pipes to deep oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks fitted and controlled as in *Vol 2, Pt 7, Ch 3, 4.8 Valves on deep tanks and their control arrangements 4.8.2*.

4.9 Water drainage

4.9.1 All fuel oil storage, settling and service tanks are to be provided with a means of removing water from the lowest point in the tank.

4.9.2 Open drains for removing water from oil tanks are to be fitted with valves or cocks of self-closing type, and suitable provision is to be made for collecting the oily discharge.

4.10 Relief on valves on oil heaters

4.10.1 Relief valves are to be fitted on the oil side of heaters and are to be adjusted to operate at a pressure of 3,4 bar above that of the supply pump relief valve, *see Vol 2, Pt 7, Ch 3, 4.3 Relief valves on pumps*. The discharge from the relief valves is to be led to a safe position.

4.11 Filling arrangements

4.11.1 Filling stations are to be isolated from other spaces and are to be efficiently drained and ventilated.

4.11.2 Provision is to be made against over-pressure in the filling pipelines, and any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position.

4.11.3 The arrangements for filling fuel oil tanks are to be such that the tanks will not be subject to a pressure in excess of that for which they were designed. Maximum filling rates are to be stated in the ship's Operations Manual.

4.12 Transfer arrangements

4.12.1 Provision is to be made for the transfer of fuel oil from any fuel oil storage or settling tank to any other fuel oil storage or settling tank in the event of fire or damage.

4.13 Alternative carriage of fuel oil and water ballast

4.13.1 Where it is intended to carry fuel oil and water ballast in the same compartments alternatively, the valves or cocks connecting the suction pipes of these compartments with the ballast pump and those connecting them with the fuel oil transfer pump are to be so arranged that the oil may be pumped from any one compartment by the fuel oil pump at the same time as the ballast pump is being used on any other compartment.

4.13.2 Attention is drawn to regulations that may be specified by the Naval Administration in connection with the *International Convention for the Prevention of Pollution of the Sea by Oil, 1973/78*.

4.14 Deep tanks for the alternative carriage of oil or water ballast

4.14.1 In the case of deep tanks which can be used for the carriage of fuel oil or water ballast, provision is to be made for blank flanging the oil and water ballast filling and suction pipes.

4.15 Fresh water piping

4.15.1 Pipes in connection with compartments used for storing fresh water are to be separate and distinct from any pipes which may be used for oil or oily water, and are not to be led through tanks which contain oil, nor are oil pipes to be led through fresh water tanks.

4.16 Independent/separate fuel oil tanks

4.16.1 Where separate fuel oil tanks are permitted, their construction is to be in accordance with the requirements of *Vol 2, Pt 7, Ch 3, 4.16 Independent/separate fuel oil tanks 4.16.2* to *Vol 2, Pt 7, Ch 3, 4.16 Independent/separate fuel oil tanks 4.16.6*, *see also Vol 2, Pt 7, Ch 3, 2.9 Precautions against fire 2.9.1*and *Vol 2, Pt 7, Ch 3, 2.9 Precautions against fire 2.9.2*.

4.16.2 In general, the minimum thickness of the plating of service, settling and other oil tanks, where they do not form part of the structure of the ship, is to be 5 mm, but in the case of very small tanks, the minimum thickness may be 3 mm.

4.16.3 For rectangular steel tanks of welded construction, the plate thicknesses are to be not less than those indicated in *Table 3.4.1 Plate thickness of separate fuel oil tanks*. The stiffeners are to be of approved dimensions.

Table 3.4.1 Plate thickness of separate fuel oil tanks

Thickness of plate, mm	Head from bottom of tank to top of overflow pipe, metres				
	2,5	3,0	3,7	4,3	4,9
	Breadth of panel, mm				
5	585	525	–	–	–
6	725	645	590	–	–
7	860	770	700	650	–
8	1000	900	820	750	700
10	1280	1140	1040	960	900

4.16.4 The dimension given in *Table 3.4.1 Plate thickness of separate fuel oil tanks* for the breadth of the panel is the maximum distance allowable between continuous lines of support, which may be stiffeners, washplates or the boundary of the tank.

4.16.5 Where necessary, stiffeners are to be provided, and if the length of the stiffener exceeds twice the breadth of the panel, horizontal stiffeners are also to be fitted, or, alternatively, tie bars are to be provided between stiffeners on opposite sides of the tank.

4.16.6 On completion, the tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

4.17 Fuel oil service tanks

4.17.1 A fuel oil service tank is a a fuel oil tank which contains only the required quality of fuel ready for immediate use.

4.17.2 Two fuel oil service tanks, for each type of fuel used on board, necessary for propulsion and generator systems, are to be provided. Each tank is to have a capacity for at least eight hours operation at sea, at maximum continuous rating of the propulsion plant and/or generating plant associated with that tank.

4.17.3 A greater or lesser period than the 8 hour period specified in *Vol 2, Pt 7, Ch 3, 4.17 Fuel oil service tanks 4.17.2* may be considered in conjunction with the operational requirements of the ship and any assigned Service Restriction.

4.18 Water compensated fuel oil tanks

4.18.1 The use of water compensated fuel oil tanks is to be avoided whenever practicable and attention is drawn to regulations that may be specified by the Naval Administration in connection with the *International Convention for the Prevention of Pollution of the Sea by Oil, 1973/78*.

4.18.2 Where the ship design considerations require the inclusion of sea-water compensated fuel oil tanks the arrangements are to comply with the requirements in*Vol 2, Pt 7, Ch 3, 4.18 Water compensated fuel oil tanks 4.18.3*. Acceptance of water compensated fuel oil tanks is subject to the provision of alternative fuel oil storage and usage arrangements that do not rely only on the use of water compensated tanks and that permit fuel oil to settle before use. The arrangement and capacity of fuel oil in tanks that do not have sea-water compensation arrangements are to recognise the service profile required by *Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.1*

4.18.3 Tank types to be used as sea-water compensated fuel tanks are listed in order of preference below. Preference is based on tank shape and the ability to readily pump out the contents:

(a) Wing or deep tanks.
(b) Wing double bottom tanks.
(c) Flat double bottom tanks.

4.18.4 The tank design is to limit the oil/water interface to reduce mixing to the minimum.

4.18.5 The internal structure of tanks is to allow free drainage to the lowest part of the tanks.

4.18.6 The tank internal preservation is to be suitable for both sea-water and fuel oil and capable of resisting microbiological contamination, specifically sulphate reducing bacteria.

4.18.7 All tanks are to have vertical longitudinal partitions (either of the fixed structural or flexible membrane type) with provision for sequential displacement of fluids in partitioned sections. The partitioned section furthest from the suction is to be provided with a suitable air pipe.

4.18.8 Means are to be provided to detect the fuel/water interface to allow accurate detection of remaining fuel in tanks.

4.18.9 The piping arrangements at the filling and discharge points are to be designed to minimise fluid turbulence.

4.18.10 The design fuel oil filling and sea-water discharge flow rates are to be specified by the Naval Administration. The fuel oil filling rate is to be achieved by use of filling trunks or other regulating method that will always provide sufficient head of oil to displace water from the water compensated fuel tanks and prevent a tank being subjected to a pressure greater than that for which it has been designed.

4.18.11 The discharge of sea-water is to be via either:

(a) A high level discharge point above waterline for discharge to shore or lighter.
(b) Low level discharge just below waterline for discharging at sea.

Means are to be provided to ascertain actual discharge of sea-water at a position close to the ship-side discharge valve.

4.18.12 Header tanks for supply of sea-water to water compensated fuel oil tanks are to be provided with level indication that can be readily sighted. Where the HP seawater main is used to supply the header tanks, arrangements are to be made to prevent the oil tanks being subject to a pressure that exceeds the design pressure. Arrangements are also to be made to ensure that oil does not enter a header tank.

4.18.13 Where a water compensated fuel oil storage system is required to be capable of displacing fuel oil direct to a service tank in the event of a transfer pump or centrifuge failure, testing is to be carried out to demonstrate that the specified transfer rate can be achieved.

4.19 Arrangements for fuels with a flash point between 43° and 60°

4.19.1 Fuel oil tanks other than those in double bottom compartments are to be located outside Category A machinery spaces, *see also Vol 1, Pt 3, Ch 2, 4.9 Cofferdams*.

4.19.2 Provisions are to be made for the measurement of fuel oil temperature at the pump suction pipe.

4.19.3 Stop valves are to be provided at the inlet and outlet side of fuel oil strainers.

4.19.4 Pipe joints are to be either welded or spherical type union joints.

■ *Section 5*
Steam piping systems

5.1 Provision for expansion

5.1.1 In all steam piping systems, provision is to be made for expansion and contraction to take place without unduly straining the pipes.

5.1.2 Where expansion pieces are used, particulars are to be submitted.

5.1.3 For installation requirements regarding expansion pieces, *see Vol 2, Pt 7, Ch 1, 14.2 Applications*.

5.2 Drainage

5.2.1 The slope of the pipes and the number and position of the drain valves or cocks are to be such that water can be efficiently drained from any portion of the steam piping system when the ship is in normal trim and is either upright or has a list of up to 5°.

5.2.2 Arrangements are to be made for ready access to the drain valves or cocks.

5.2.3 For the drainage of boiler and exhaust gas economiser safety valves, *see Vol 2, Pt 8, Ch 1, 15.2 Safety valves 15.2.8* and *Vol 2, Pt 8, Ch 1, 15.2 Safety valves 15.2.9*.

5.3 Soot cleaning drains

5.3.1 The capacity of the drains from exhaust gas economisers/boilers is to be sufficient to remove all wash water or condensate generated by installed washing systems, and arrangements are to be such that engines and turbochargers are protected from wash water or condensate drainage from the washing system.

5.3.2 Adequate arrangements are to be made for the collection and disposal of the waste water generated during periodic water washing of the exhaust gas economiser/boiler. Details are to be submitted for approval.

5.4 Reduced pressure lines

5.4.1 Pipelines which are situated on the low pressure side of reducing valves, and which are not designed to withstand the full pressure at the source of supply, are to be fitted with pressure gauges and with relief valves having sufficient discharge capacity to protect against excessive pressure.

Section 6
Boiler feed water, condensate and thermal fluid circulation systems

6.1 Feed water piping

6.1.1 Two separate means of feed are to be provided for all main and auxiliary boilers which are required for Mobility or Ship Type systems. In the case of steam/steam generators, one means of feed will be accepted provided steam for Mobility or Ship Type systems is available simultaneously from another source.

6.2 Feed and circulation pumps

6.2.1 Two or more feed pumps are to be provided of sufficient capacity to supply the boilers under full load conditions with any one pump out of action.

6.2.2 Independent feed pumps required for feeding the main boilers are to be fitted with automatic regulators for controlling their output.

6.2.3 The valves on the suction pipes from the hotwell or condenser and the feed drain tank or filter are to be of the non-return type.

6.2.4 The arrangement of forced water/thermal fluid circulation pumps for exhaust gas economisers/boilers/ thermal heaters is to be such that where required, the flow through the exhaust gas economiser/boiler/thermal heater is to be established prior to engine start up. Where applicable, provision is to be made to allow for operation in the dry condition.

6.2.5 The forced circulation flow required by *Vol 2, Pt 7, Ch 3, 6.2 Feed and circulation pumps 6.2.4* is to be maintained on completion of engine shutdown for a sufficient duration in accordance with the exhaust gas economiser/boiler/thermal heater manufacturer's instructions. Details of arrangements are to be submitted for approval.

6.2.6 Where arrangements are such that exhaust gas economisers/boilers/thermal heaters require forced water /thermal fluid circulation, standby pumps are to be fitted. The standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

6.3 Condensate pumps

6.3.1 Two or more extraction pumps are to be provided for dealing with the condensate from the main and auxiliary condensers, at least one of which is to be independently driven. Where one of the independent feed pumps is fitted with direct suctions from the condensers and a discharge to the feed tank, it may be accepted for this purpose.

6.4 Valves and cocks

6.4.1 Feed and condensate pumps are to be provided with valves or cocks, interposed between the pumps and the suction and the discharge pipes, so that any pump may be opened up for overhaul while the others continue in operation.

6.5 Reserve feed water

6.5.1 All ships fitted with boilers are to be provided with storage space for reserve feed water, the structural and piping arrangements being such that this water cannot be contaminated by oil or oily water.

6.5.2 For main boilers, one or more evaporators, of adequate capacity, are also to be provided.

6.6

6.6.1 For feed water level regulators for water tube boilers, *see Vol 2, Pt 8, Ch 1, 16.8 Feed check valves and water level regulators*.

Section 7
Engine cooling water systems

7.1 General

7.1.1 Provision is to be made for an adequate supply of cooling water to the main propelling machinery and auxiliary engines for other Mobility and/or Ship Type systems, also to the lubricating oil and fresh water coolers and air coolers for electric propelling machinery, where these coolers are fitted. The cooling water pump(s) may be worked from the engines or be driven independently.

7.1.2 In the case of main steam turbine installations, a sea inlet scoop arrangement may replace the main sea-water circulating pump, subject to the conditions stated in *Vol 2, Pt 7, Ch 3, 7.2 Standby supply 7.2.2*.

7.2 Standby supply

7.2.1 Provision is also to be made for a separate supply of cooling water from a suitable independent pump of adequate capacity.

7.2.2 The following arrangements are acceptable depending on the purpose for which the cooling water is intended:

(a) Where only one main engine is fitted, the standby pump is to be connected ready for immediate use.
(b) Where more than one main engine is fitted, each with its own pump, a complete spare pump of each type may be accepted.
(c) Where a sea inlet scoop arrangement is fitted, and there is only one independent condenser circulating pump, a further pump, or a connection to the largest available pump suitable for circulation duties, is to be fitted to provide the second means of circulation when the ship is manoeuvring. The pump is to be connected ready for immediate use.
(d) Where fresh water cooling is employed for main and/or auxiliary engines, a standby fresh water pump need not be fitted if there are suitable emergency connections from a salt water system.
(e) Where each auxiliary is fitted with a cooling water pump, standby means of cooling need not be provided.

Where, however, a group of auxiliaries is supplied with cooling water from a common system, a standby cooling water pump is to be provided for this system. This pump is to be connected ready for immediate use and may be a suitable general service pump.

7.3 Selection of standby pumps

7.3.1 When selecting a pump for standby purposes, consideration is to be given to the maximum pressure which it can develop if the overboard discharge valve is partly or fully closed and, when necessary, condenser doors, water boxes, etc. are to be protected by an approved device against inadvertent over-pressure. *See Vol 2, Pt 1, Ch 3, 9.4 Hydraulic tests 9.4.4* for the hydraulic test pressure which condensers are required to withstand.

7.4 Relief valves on main cooling water pumps

7.4.1 Where cooling water pumps can develop a pressure head greater than the design pressure of the system, they are to be provided with relief valves on the pump discharge effectively to limit the pump discharge pressure to the design pressure of the system. For location of relief valves, *see Vol 2, Pt 7, Ch 2, 7.6 Location of fittings*.

7.5 Sea inlets

7.5.1 Not less than two sea inlets are to be provided for the pumps supplying the sea-water cooling system, one for the main pump and one for the standby pump. Alternatively, the sea inlets may be connected to a suction line available to main and standby pumps.

7.5.2 Where standby pumps are not connected ready for immediate use (*see Vol 2, Pt 7, Ch 3, 7.2 Standby supply 7.2.2*), the main pump is to be connected to both sea inlets.

7.5.3 Cooling water pump sea inlets are to be low inlets and one of them may be the ballast pump or general service pump sea inlet.

7.5.4 The auxiliary cooling water sea inlets are to be located one on each side of the ship.

7.6 Strainers

7.6.1 Where sea-water is used for the direct cooling of the main engines and auxiliary engines for other Mobility and/or Ship Type systems, the cooling water suction pipes are to be provided with strainers which can be cleaned without interruption to the cooling water supply.

7.7 Cooling systems

7.7.1 Means are to be provided for the drainage and storage of engine coolants to enable maintanance and repair of the engine.

7.7.2 All cooling systems are to be provided with means of venting air at high points and sufficient drain fittings to enable the system to be completely drained for maintenance.

7.8

7.8.1 For guidance on metal pipes for water services, *see Vol 2, Pt 7, Ch 1, 17 Guidance notes on metal pipes for water service*.

■ *Section 8*
Lubricating oil systems

8.1 General requirements

8.1.1 The arrangements for storage, distribution and utilisation of lubricating oils are to comply with the requirements of this Section.

8.2 Pumps

8.2.1 Where lubricating oil for the main engine(s) is circulated under pressure, a standby lubricating oil pump is to be provided where the following conditions apply:

(a) The lubricating oil pump is independently driven and the total output of the main engine(s) exceeds 370 kW.
(b) One main engine with its own pump is fitted and the output of the engine exceeds 370 kW.
(c) More than one main engine each with its own lubricating oil pump is fitted and the output of each engine exceeds 370 kW.

8.2.2 The standby pump is to be of sufficient capacity to maintain the supply of oil for normal conditions with any one pump out of action. The pump is to be fitted and connected ready for immediate use. In all cases satisfactory lubrication of the engines is to be ensured while starting and manoeuvring.

8.2.3 Similar provisions to those of *Vol 2, Pt 7, Ch 3, 8.2 Pumps 8.2.1* and *Vol 2, Pt 7, Ch 3, 8.2 Pumps 8.2.2* are to be made where separate lubricating oil systems are employed for piston cooling, reduction gears, oil operated couplings, controllable pitch propellers, water jet systems and propulsion thrusters, unless approved alternative arrangements are provided.

8.2.4 Independently driven pumps of rotary type are to be fitted with a non-return valve on the discharge side of the pump.

8.3 Control of pumps

8.3.1 The power supply to all independently driven lubricating oil transfer and pressure pumps is to be capable of being stopped from a position outside the space, which will always be accessible in the event of fire occurring in the space in which the pumps or pump compartment are situated.

8.4 Relief valves on pumps

8.4.1 All lubricating oil pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves or equivalent. Each relief valve is to be in closed circuit, i.e. arranged to discharge back to the suction side of the pump, thereby limiting the pump discharge pressure to the design pressure of the system.

8.4.2 Where centrifugal type lubricating oil pumps are fitted, pressure relief valves will not be required provided that pipes, valves and fittings are suitable for the greater of the design pressure or pump non-delivery pressure.

8.5 Alarms

8.5.1 All main and auxiliary engines and turbines intended for Mobility systems or Ship Type systems are to be provided with means of indicating the lubricating oil pressure supply to them. Where such engines and turbines are of more than 37 kW, audible and visual alarms are to be fitted to give warning of an appreciable reduction in pressure of the lubricating oil supply. Further, these alarms are to be actuated from the outlet side of any restrictions, such as filters, coolers, etc.

8.6 Emergency supply for propulsion turbines and propulsion turbo-generators

8.6.1 A suitable emergency supply of lubricating oil is to be arranged to come automatically into use in the event of a failure of the supply from the pump.

8.6.2 The emergency supply may be obtained from gravity tank containing sufficient oil to maintain adequate lubrication for not less than six minutes, and, in the case of propulsion turbo-generators, until the unloaded turbine comes to rest from its maximum rated running speed.

8.6.3 Alternatively, the supply may be provided by the standby pump or by an emergency pump. These pumps are to be so arranged that their availability is not affected by a failure in the power supply.

8.6.4 For automatic shutdown arrangements of main turbines in the event of failure of the lubrication system, *see Vol 2, Pt 2, Ch 2, 5.1 General* and *Vol 2, Pt 2, Ch 3, 4.3 Stress raisers*.

8.7 Maintenance of bearing lubrication

8.7.1 The arrangements for lubricating bearings and for draining crankcase and other oil sumps of main and auxiliary engines, gearcases, electric generators, motors, and other running machinery are to be so designed that lubrication will remain efficient with the ship inclined under the conditions as shown in *Vol 2, Pt 1, Ch 3, 4.6 Inclination of ship*.

8.7.2 For details of the requirements relating to the lubrication of bearings of electric generators and motors, *see Vol 2, Pt 9, Ch 1, 2.3 Ambient reference and operating conditions* and *Vol 2, Pt 7, Ch 3, 9 Control, supervision and monitoring of equipment*.

8.7.3 Where a filling pipe and cap are provided for engines and other machinery, provision is to be made for the topping up oil to pass through a gauze strainer. The caps are to be capable of being secured in the closed position.

8.7.4 The capacity of lubricating oil service tanks is to be sufficient to avoid the need to replenish a tank for a period of time agreed by the Owner, assuming the normal oil consumption rate quoted by the equipment manufacturer.

8.8 Filters

8.8.1 Where the lubricating oil for main propelling engines is circulated under pressure, provision is to be made for the efficient filtration of the oil. The filters are to be capable of being cleaned without stopping the engine or reducing the supply of filtered oil to the engine. Proposals for an automatic by-pass for emergency purposes in high speed engines are to be submitted for special consideration.

8.8.2 In the case of propulsion turbines and their gears, arrangements are to be made for the lubricating oil to pass through magnetic strainers and fine filters. Generally, the openings in the filter elements are to be not coarser than required by the manufacturer of the turbines, especially for the supply to turbine thrust bearings.

8.8.3 Centrifuges used for lubricating oil treatment are to be type tested for use on board ships in accordance with a national or international standard that is acceptable to LR.

8.9 Filling arrangements

8.9.1 Filling stations are to be isolated from other spaces and are to be efficiently drained and ventilated.

8.10 Cleanliness of pipes and fittings

8.10.1 Extreme care is to be taken to ensure that lubricating oil pipes and fittings, before installation, are free from scale, sand, metal particles and other foreign matter.

8.11 Pipes conveying oil

8.11.1 Pipes conveying lubricating oil under pressure are to be of seamless steel or other approved material having flanged or welded joints, and are to be placed in sight above the platform in well lit and readily accessible parts of the machinery spaces. The number of flanged joints is to be kept to a minimum.

8.11.2 For requirements relating to flexible hoses, *see Vol 2, Pt 7, Ch 1, 13 Flexible hoses*.

8.12 Lubricating oil drain tank

8.12.1 Where an engine lubricating oil drain tank extends to the bottom shell plating in ships that are required to be provided with a double bottom, a shut-off valve is to be fitted in the drainpipe between the engine casing and the double bottom tank. This valve is to be capable of being closed from an accessible position above the level of the lower platform.

8.13 Lubricating oil contamination

8.13.1 The materials used in the storage and distribution of lubricating oil are to be selected such that they do not introduce contamination or modify the properties of the oil. The use of cadmium or zinc in lubricating oil systems where they may come into contact with the oil is not permitted.

8.13.2 Arrangements are to be made for each forced lubrication system, renovation system, ready to use tank(s) and their associated run-down lines to drain tanks to be flushed after system installation and prior to running of machinery. The flushing arrangements and procedures are to be in accordance with the equipment manufacturer's procedures and recommendations.

8.13.3 For prevention of ingress of water into lubricating oil tanks via air pipes, *see Vol 2, Pt 7, Ch 2, 10.4 Termination of air pipes 10.4.4*.

8.13.4 The design and construction of engine and gear box piping arrangements are to prevent contamination of engine lubricating oil systems by leakage of cooling water or from bilge water where the engines or gear boxes are partly installed below the lower platform. Where flexibility is required to accommodate movement between the engine and sump tank, any flexible joint assembly is to be of an approved type suitable for its intended application.

8.13.5 Where there is a permanently attached oil filling pipe and cap provided for an engine or other item of machinery, provision is to be made for the topping up oil to safely pass through a suitable strainer to prevent unwanted matter getting into the lubricating oil system. The caps are to be capable of being secured in the closed position.

8.13.6 Sampling points are to be provided that enable samples of lubricating oil to be taken in a safe manner. The sampling arrangements are to have the capability to provide samples when machinery is running and are to be provided with valves and cocks of the self-closing type and located in positions as far removed as possible from any heated surface or electrical equipment.

8.14 Security

8.14.1 All valves whose position can affect the supply of oil to lubrication consumers are to be capable of being secured in their operating position.

8.14.2 All means of entry into lubricating oil tanks and gearcases are to be provided with a means of being locked in the closed position.

8.14.3 Drain plugs and cocks in lubricating systems are to be capable of being secured in the closed position.

8.15 Deep tank valves and their control arrangements

8.15.1 The requirements for remote operation on valves on deep tank suction pipes may be waived where the valves are closed during normal operation.

8.15.2 Remotely operated valves on lubricating oil deep tank suctions should not be of the quick-closing type where inadvertent use would endanger the safe operation of the main propulsion and essential auxiliary machinery.

8.15.3 Every lubricating oil suction pipe from a storage, settling and service tank situated above the double bottom, and every oil levelling pipe within the engine room, is to be fitted with a valve or cock secured to the tank.

8.15.4 Valves and cocks are to be capable of being closed locally and from positions outside the space in which the tank is located. The remote controls are to be accessible in the event of fire occurring in the deep tank’s space. Instructions for closing the valves or cocks are to be indicated at the valves and cocks and at the remote control positions.

8.15.5 In the case of tanks of less than 500 litres capacity, consideration will be given to the omission of remote controls.

8.15.6 Every lubricating oil suction pipe which is led into the engine space from a tank situated above the double bottom outside this space is to be fitted in the machinery space with a valve controlled as in *Vol 2, Pt 7, Ch 3, 8.15 Deep tank valves and their control arrangements 8.15.4*, except where the valve on the tank is already capable of being closed from an accessible position above the bulkhead deck.

8.15.7 Where the filling pipes to deep lubricating oil tanks are not connected to the tanks near the top, they are to be provided with non-return valves at the tanks or with valves or cocks, fitted and controlled as in *Vol 2, Pt 7, Ch 3, 8.15 Deep tank valves and their control arrangements 8.15.4*.

8.16 Separate oil tanks

8.16.1 On completion, the tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected.

8.17

8.17.1 For air, sounding pipes and gauge glasses, *see Vol 2, Pt 7, Ch 2, 10 Air, overflow and sounding pipes*.

For hydraulic power actuating systems, *see Vol 2, Pt 7, Ch 5, 11 Hydraulic power actuating systems*.

■ *Section 9*
Control, supervision and monitoring of equipment

9.1 General

9.1.1 The control and monitoring systems are to comply with the requirements of *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*.

9.2 Automatic and remote controls

9.2.1 Where equipment is fitted with automatic or remote control so that under normal operating conditions it does not require manual intervention by operators, it is to be provided with alarms and safety arrangements required by *Vol 2, Pt 7, Ch 3, 9.3 Thermal fluid heaters* to *Vol 2, Pt 7, Ch 3, 9.5 Miscellaneous machnery*.

9.2.2 Where machinery specified in this Section is required to be provided with a standby pump, the standby pump is to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

9.2.3 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery are required in the relevant Tables of this Section, the sensors and circuits utilised for the second stage alarm and automatic shutdown are to be independent of those required for the first stage alarm.

9.3 Thermal fluid heaters

9.3.1 Alarms and safeguards are indicated in *Vol 2, Pt 7, Ch 3, 9.3 Thermal fluid heaters 9.3.2* and *Table 3.9.1 Thermal fluid heaters: Alarms and safeguards*.

Table 3.9.1 Thermal fluid heaters: Alarms and safeguards

Item
Expansion* tank level
Thermal fluid flow
Thermal fluid pressure
Thermal fluid outlet temperature*
Thermal fluid outlet temperature*
Thermal fluid forced circulation flow (if fitted)
Combustion air pressure*
Fuel oil pressure*
Fuel oil temperature or viscosity*
Fuel oil atomising steam/air pressure
Burner flame*
Flame monitoring device(s)*
Igniter*
Forced draft fan*
Air register and dampers (including those in the uptake)*
Control system*
Uptake temperature

Note 1. Special consideration may be given to the requirements for oil fired hot water heaters.

Note 2. For heaters not supplying Ancillary systems, only the items marked* are required.

Note 3. These safeguards are to remain operative during automatic, manual and emergency operation.

Note 4. Alarm and Fuel oil shut-off only required where exhaust gas economisers/boilers are fitted.

Note 5. For exhaust gas economisers/boilers requiring thermal fluid forced circulation, the low flow alarm is to be fitted with provision to override the alarm if t

Note 6. Alternatively, details (including location) of an appropriate fire detection system are to be submitted for consideration.

9.3.2 The standby pumps for fuel oil and thermal fluid circulation are to start automatically when the discharge pressure from the working pump falls below a predetermined value. The standby pumps for thermal fluid circulation are to start before the shut-offs due to low thermal fluid pressure, *see Table 3.9.1 Thermal fluid heaters: Alarms and safeguards*, are activated.

9.3.3 The following heater services are to be fitted with automatic controls so as to maintain steady state conditions throughout the operating range of the heater:

(a) Combustion system.
(b) Fuel oil supply temperature or viscosity, heavy oil only.
(c) Thermal fluid temperature.

9.3.4 Burner controls are to be arranged such that lightoff is only possible at the minimum firing rate compatible with flame establishment. If ignition is set to occur at a fuel rich condition the burner is to revert to the correct operating air/fuel ratio on establishment of a stable flame.

9.3.5 Burner fuel oil valve(s) are not to open:

- prior to completion of required warm up times; or
- when the power supply to the igniter has failed; or

- prior to the completion of furnace purging, *see Vol 2, Pt 7, Ch 3, 3.1 Oil burning units 3.1.9*.

9.3.6 Arrangements for flame failure detection are to be provided with self-monitoring capabilities which prove that the flame detector is not erroneously indicating the presence of a flame. In the event of failure being detected by these selfmonitoring capabilities:

- fuel oil to burner is to be shut off automatically; and
- an alarm is to be activated.

9.3.7 Where established as necessary by *Vol 2, Pt 7, Ch 3, 3.1 Oil burning units 3.1.10*means are to be provided to prevent starting of the ignition sequence following multiple flame failures until completion of the identified lock out period.

9.3.8 Following burner shutdown, the furnace is to be purged automatically for at least the required pre-purging time. In event of shutdown due to activation of a required safeguard this purging is to be manually initiated.

9.4 Incinerators

9.4.1 Alarms and safeguards are indicated in *Vol 2, Pt 7, Ch 3, 9.4 Incinerators 9.4.2*, *Vol 2, Pt 7, Ch 3, 9.4 Incinerators 9.4.3* and *Table 3.9.2 Incinerators: Alarms and safeguards*.

Table 3.9.2 Incinerators: Alarms and safeguards

Item	Alarm	Note
Fuel oil temperature or viscosity	High and low	Heavy oil and sludge
Fuel oil pressure	Low	—
Combustion air pressure	Low	Fuel oil and/or sludge to burners to be shut off automatically
Burner flame and ignition	Failure	Fuel oil and/or sludge to burners to be shut off automatically *See* Note
Furnace temperature	High	Fuel oil and/or sludge to burners to be shut off automatically
Furnace temperature	Low	If applicable
Exhaust temperature	High	—
Note Combustion spaces are to be purged automatically before re-ignition takes place in the event of a flame out on all burners.		

9.4.2 Where arrangements are provided to introduce solid waste into the furnace these are to be such that there is no risk of a fire hazard.

9.4.3 The combustion temperature is to be controlled to ensure that all liquid and solid waste is efficiently burned without exceeding predetermined temperature limits.

9.5 Miscellaneous machnery

9.5.1 Alarms and safeguards are indicated in *Vol 2, Pt 7, Ch 3, 9.5 Miscellaneous machnery 9.5.2* to *Vol 2, Pt 7, Ch 3, 9.5 Miscellaneous machnery 9.5.5* and *Table 3.9.3 Miscellaneous machinery: Alarms and safeguards*.

Table 3.9.3 Miscellaneous machinery: Alarms and safeguards

Item	Alarm	Note
Coolant tanks level	Low	—
Fuel oil service tanks level	High and Low	Where a common overflow tank is fitted, a high level alarm in the common overflow tank may be accepted
Fuel oil service tanks temperature	High	Where heating arrangements are fitted
Fuel oil settling tanks temperature	High	Where heating arrangements are fitted

Sludge tanks level	High	—
Feed water tanks level	Low	Service tank only
Purifier water seal broken	Fault	—
Purifier oil inlet temperature	High	—
Air compressor lubricating oil	Failure	Automatic shutdown
Air compressor discharge air temperature	High	—
Hydraulic control system pressure	Low	—
Pneumatic control system pressure	Low	
Oil heater temperature	High	*See also Vol 2, Pt 7, Ch 3 Machinery Piping Systems*
Controlled environmental conditions	Abnormal	*See also Vol 2, Pt 7, Ch 3, 9.2 Automatic and remote controls 9.2.2*

9.5.2 **Dual fuel systems**. Oil and gas dual fired systems for boilers and engines are to be provided with indication to show which fuel is in use.

9.5.3 **Oil heaters**. Fuel oil or lubricating oil heaters are to be fitted with a high temperature alarm which may be incorporated in the temperature control system. In addition to the temperature control system, an independent sensor, with manual reset, is to be fitted which will automatically cut off the heating supply in the event of excessively high temperatures or loss of flow, except where the maximum temperature of the heating medium remains limited to a value below 220°C.

9.5.4 **Oil tank electric heating**. Fuel oil and lubricating oil tanks that are provided with electric heating elements are to be fitted with a high temperature alarm, which may be incorporated in the temperature control system, a low level alarm and an additional low level sensor to cut off the power supply at a level above that at which the heating element would be exposed.

9.5.5 **Fuel oil tanks**. Means are to be provided to eliminate the possibility of overflow from fuel oil service tanks into the machinery space and to safeguard against overflow of oil from fuel oil service tanks through the air pipe. *See Vol 2, Pt 7, Ch 2 Ship Piping System* regarding the termination of air pipes.

■ *Section 10* **Multi-engined ships**

10.1 General

10.1.1 This Section is applicable to category **NS3 ships**, *see Vol 1, Pt 1, Ch 2, 2 Scope of the Rules* that have multi-engine installations for propulsion purposes.

10.1.2 For vessels in which the propulsion systems are independent and the propulsion system prime movers are also fully independent of each other such that in the event of the failure of one of the sources of propulsion power the vessels will retain the capability of safely manoeuvring under all conditions of service, the following may not be required:

(a) Spare fuel oil booster pump stipulated in *Vol 2, Pt 7, Ch 3, 3.10 Booster pumps 3.10.2*.
(b) Spare lubricating oil pump stipulated in *Vol 2, Pt 7, Ch 3, 8.2 Pumps 8.2.1*, *Vol 2, Pt 7, Ch 3, 8.2 Pumps 8.2.2* and *Vol 2, Pt 7, Ch 3, 8.2 Pumps 8.2.3*
(c) Spare cooling water pump stipulated in *Vol 2, Pt 7, Ch 3, 7.2 Standby supply 7.2.2*.

Section 11
Electrical equipment cooling arrangements

11.1 General

11.1.1 Provision is to be made for an adequate supply of cooling to the electrical equipment used in Mobility and Ship Type engineering systems. The cooling arrangements may be worked from the engineering systems or be supplied by independent means.

11.1.2 The requirements of this Section are with the goal of providing sufficient cooling whereby normal operation of Mobility and Ship Type engineering systems can be sustained or restored even though any one of the sources of cooling becomes inoperative.

11.1.3 The temperature of cooling water supplied to coolers for electrical equipment is to take account of imposed loads when under normal design operating conditions and take into account the ambient temperatures likely to be experienced in the compartment where the equipment is located.

11.1.4 The possible formation of condensation due to low cooling temperatures where high humidity is likely to occur within electrical enclosures is also to be taken into account. The ambient temperatures and anticipated humidity levels are to be declared in the System Design Description required by *Vol 2, Pt 7, Ch 3, 11.1 General 11.1.9*.

11.1.5 Where chilled water systems are used for electrical equipment cooling, the arrangements are to comply with *Vol 2, Pt 7, Ch 5 Ship Type Piping Systems* as applicable.

11.1.6 Where fresh water systems are used for electrical equipment cooling, the arrangements are to comply with *Vol 2, Pt 11, Ch 1 Made and Fresh Water Systems* as applicable.

11.1.7 Heat exchangers used in cooling systems for electrical equipment are to comply with *Vol 2, Pt 7, Ch 1, 18 Heat exchangers* as applicable.

11.1.8 Where sea-water systems are used for electrical equipment cooling, the guidance in *Vol 2, Pt 7, Ch 1, 17 Guidance notes on metal pipes for water service* of Chapter 1 is to be complied with where applicable.

11.1.9 A System Design Description for cooling systems for electrical equipment used in Mobility and Ship Type category engineering systems is to be submitted for information purposes.

11.1.10 A Risk Assessment (RA) is to be carried out for the cooling arrangements for electrical equipment used in Mobility and Ship Type category systems. The analysis is to be in accordance with *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)* and is to address the effects of failure of cooling supplies related to the ability of equipment and systems to operate with short-term loss of cooling and to operate with any reduced standby cooling capability.

11.1.11 Reference is also to be made to the following Rules as applicable:

(a) Location of pipes, joints and fittings - *Vol 2, Pt 7, Ch 2, 2.8 Miscellaneous requirements 2.8.2*.
(b) Cooling of electrical rotating machine enclosures - *Vol 2, Pt 9, Ch 2, 6.6 Machine enclosure 6.6.1*.
(c) Cooling of transformers - *Vol 2, Pt 9, Ch 3, 7.1 Transformers 7.1.10* and *Vol 2, Pt 9, Ch 3, 7.1 Transformers 7.1.11*.
(d) Cooling of semiconductor equipment - *Vol 2, Pt 9, Ch 3, 7.2 Semiconductor converters 7.2.4*.

11.2 Standby supply

11.2.1 Where the continuous operation of electrical equipment used in Mobility or Ship Type engineering systems is susceptible to interruptions in cooling arrangements (water or air), standby cooling arrangements are to be provided. In general, the standby cooling arrangements are to be automatically and immediately brought into effect on failure of the normal cooling supply. Such standby cooling arrangements may need to be supplied from an emergency source of power if the cooling is essential to the survivability of an item of equipment.

11.2.2 Where cooling arrangements are by cooling water system(s), provision is to be made for a separate supply of cooling water from a suitable independent pump of adequate capacity. The following arrangements are acceptable depending on the purpose for which the cooling water is intended:

(a) Where only one electrically powered Mobility system is fitted, the standby cooling arrangements are to be connected ready for immediate use.

(b) Where more than one electrically powered Mobility system is fitted, each with its own cooling pump, a complete spare pump of each type may be accepted. The complete spare pump is to be stored onboard such that can be readily installed if required.
(c) Where a sea inlet scoop arrangement is fitted, and there is only one independent cooling pump, a further pump, or a connection to the largest available pump suitable for cooling duties, is to be fitted to provide the second means of cooling when the ship is manoeuvring. The pump is to be connected ready for immediate use.
(d) Where fresh water cooling is employed for electrically powered Mobility systems, a standby fresh water pump need not be fitted if there are suitable emergency connections from a salt water system.
(e) Where each auxiliary item of electrically powered mobility equipment is fitted with a cooling water pump, standby means of cooling need not be provided.

Where, however, a group of auxiliaries is supplied with cooling water from a common system, a standby cooling water pump is to be provided for this system. This pump is to be connected ready for immediate use and may be a suitable general service pump.

11.3 Selection of standby pumps

11.3.1 When selecting a pump for standby purposes, consideration is to be given to the maximum pressure which it can develop if the overboard discharge valve is partly or fully closed and, when necessary, end covers, water boxes, etc. are to be protected by an approved device against inadvertent over-pressure.

11.4 Relief valves on main cooling water pumps

11.4.1 Where cooling water pumps can develop a pressure head greater than the design pressure of the system, they are to be provided with relief valves on the pump discharge to effectively limit the pump discharge pressure to the design pressure of the system. For location of relief valves, *see Vol 2, Pt 7, Ch 2, 7.6 Location of fittings*.

11.5 Sea inlets

11.5.1 Not less than two sea inlets are to be provided for the pumps supplying a sea-water cooling system, one for the main pump and one for the standby pump. Alternatively, the sea inlets may be connected to a suction line available to main and standby pumps.

11.5.2 Where standby pumps are not connected ready for immediate use (*see Vol 2, Pt 7, Ch 3, 11.2 Standby supply 11.2.2*), the main pump is to be connected to both sea inlets.

11.5.3 Cooling water pump sea inlets are to be low inlets and one of them may be the ballast pump or general service pump sea inlet.

11.5.4 Auxiliary cooling water sea inlets are to be located one on each side of the ship.

11.5.5 Where sea inlets are connected to a common suction line serving main and standby cooling water pump units, the arrangements are to be such that a failure in the common suction line will not cause loss of sea-water supply to both pumps at the same time.

11.6 Strainers

11.6.1 Where sea-water is used for the direct cooling of electrically powered Mobility and Ship Type systems, the cooling water suction pipes are to be provided with strainers that will prevent debris being introduced into the cooling systems. The strainer arrangements are to be such that a strainer can be cleaned without interruption to the cooling water supply whilst the electrically powered equipment is in operation at its rated capacity.

11.6.2 In general, the aperture openings in primary strainers should not exceed 10 mm diameter and for secondary strainers not less than 5 mm diameter. The open area through any strainer is to be not less than twice the area of the inlet valve to the strainer. Where it is proposed to use secondary strainers with apertures less than 5 mm diameter, the implications of using such are to be assessed by the manufacturer and included in the operating and maintenance manual.

11.7 Cooling systems

11.7.1 Means are to be provided for the drainage and where necessary the storage of coolants, to enable maintenance and repair of the coolers and equipment.

11.7.2 All cooling systems are to be provided with means of venting air at high points and sufficient drain fittings to enable the system to be completely drained for maintenance.

11.8 Alarms

11.8.1 Cooling water systems for electrical equipment in Mobility and Ship Type engineering systems are to be provided with high temperature and low flow alarms.

■ Section 12
Air compressors and air starting arrangements

12.1 General requirements

12.1.1 The requirements of this Section are applicable to reciprocating air compressors intended for starting main engines and auxiliary engines providing essential services and are applicable to both reciprocating internal combustion engines and gas turbine engines.

12.1.2 Two or more air compressors are to be fitted having a total capacity, together with a topping-up compressor where fitted, capable of charging the air receivers within one hour from atmospheric pressure, to the pressure sufficient for the number of starts required by *Vol 2, Pt 7, Ch 3, 12.12 Air receivers*. At least one of the air compressors is to be independent of the main propulsion unit and the capacity of the main air compressors is to be approximately equally divided between them. The capacity of an emergency compressor which may be installed to satisfy the requirements of *Vol 2, Pt 7, Ch 3, 12.11 Dead ship condition starting arrangements* is to be ignored.

12.1.3 The compressors are to be so designed that the temperature of the air discharged to the starting air receivers will not substantially exceed 93°C in service. A small fusible plug or an alarm device operating at 121°C is to be provided on each compressor to give warning of excessive air temperature. The emergency air compressor is excepted from these requirements.

12.1.4 Each compressor is to be fitted with a safety valve so proportioned and adjusted that the accumulation with the outlet valve closed will not exceed 10 per cent of the maximum working pressure. The casings of the cooling water spaces are to be fitted with a safety valve or bursting disc so that ample relief will be provided in the event of the bursting of an air cooler tube.

12.1.5 Each compressor is to be fitted with an alarm for failure of the lubricating oil supply which will initiate an automatic shutdown.

12.1.6 Where starting air is provided from a general use compressed air system, it is to be demonstrated that the system capacities are consistent with the philosophy described in *Vol 2, Pt 7, Ch 3, 12.1 General requirements 12.1.2*.

12.2 Plans and particulars

12.2.1 Detailed plans, particulars, dimensional drawings and material specifications for compressor crankshafts are to be submitted. Plans and particulars for other parts and calculations, where applicable, are to be submitted to LR upon request.

12.2.2 Where compressors of a special type or design are proposed, the requirements of *Pt 7, Ch 15 Refrigeration Systems and Equipment Serving Provision Stores and Air-Conditioning Installations* of the Rules for Ships are to be applied.

12.3 Materials

12.3.1 The specified minimum tensile strength of castings and forgings for compressor crankshafts are to be within the limits given in *Vol 2, Pt 2, Ch 1, 3.1 Crankshaft materials 3.1.1* and for grey cast iron to be not less than 300 N/mm^2.

12.3.2 Where it is proposed to use materials outside the ranges specified in *Vol 2, Pt 2, Ch 1, 3.1 Crankshaft materials*, details of the chemical composition, heat treatment and mechanical properties are to be submitted for approval.

12.3.3 Materials for components are to be tested as indicated in *Vol 2, Pt 2, Ch 1, 3.2 Materials test and inspections*.

12.3.4 For compressors with crankshafts with a calculated crank pin diameter equal to or greater than 50 mm, materials for components are to be tested as indicated in *Vol 2, Pt 2, Ch 1, 3.2 Materials test and inspections*. For calculated crank pin diameters less than 50 mm, a manufacturer's certificate may be accepted, *see Ch 1, 3.1 General 3.1.3* of the Rules for Materials .

12.4 Design and construction

12.4.1 A fully documented fatigue strength analysis is to be submitted, indicating a factor of safety of 1,5 at the design loads, based on a suitable fatigue strength criterion. Alternatively, the requirements of *Vol 2, Pt 7, Ch 3, 12.4 Design and construction 12.4.2* may be used.

12.4.2 The diameter, d_{p}, of a compressor crankshaft is to be not less than d, determined by the following formula, when all cranks on the shaft are located between two main bearings only:

$$d = V_{\text{c}} = \left(\frac{D^2 p\,Z}{78,5}\left(\frac{S}{16} + \frac{a\,b}{a+b}\right)\right)^{1/3} \quad \text{mm}$$

where:

a = distance between inner edge of one main bearing and the centreline of the crankpin nearest the centre of the span, in mm

b = distance from the centreline of the same crankpin to the inner edge of the adjacent main bearing, in mm

$a + b$ = span between inner edges of main bearings, in mm

d_{p} = proposed minimum diameter of crankshaft, in mm

p = design pressure, in bar *g*, as defined in *Vol 2, Pt 7, Ch 1, 3.3 Design pressure 3.3.1*

D = diameter of cylinder, in mm

S = length of stroke, in mm

V_{c} = 1,0 for shafts having one cylinder per crank, or

= 1,05 for 90° between adjacent cylinders on the same crankpin

= 1,18 for 60° between adjacent cylinders on the same crankpin

= 1,25 for 45° between adjacent cylinders on the same crankpin

for the shaft and cylinder arrangements as detailed in *Table 3.12.1 Angle between cylinders*

$$Z = \frac{560}{\sigma_{\text{u}} + 160} \quad \text{for steel}$$

$$Z = \frac{700}{\sigma_{\text{u}} + 260 - 0,059 d_{\text{p}}} \quad \text{for spheroidal or nodular graphite cast iron}$$

$$Z = \frac{700}{\sigma_{\text{u}} + 260 - 0,069 d_{\text{p}}} \quad \text{for grey cast iron}$$

$\boldsymbol{\sigma}_{\text{u}}$ = specified minimum tensile strength of crankshaft material, in N/mm^2.

Table 3.12.1 Angle between cylinders

Number of crankpins	Number of cylinders per crank	Angle between cylinders, in degrees		
1 or 2	2	45	60	90
3	2	45	60	–
4	2	45	60	–
1	3	45	60	90
2	3	45	60	–
3	3	45	–	–
1	4	45	60	–
2	4	45	–	–

12.4.3 Where the shaft is supported additionally by a centre bearing, the diameter is to be evaluated from the half shaft between the inner edges of the centre and outer main bearings. The diameter so found for the half shaft is to be increased by six per cent for the full length shaft diameter.

12.4.4 The dimensions of crankwebs are to be such that Bt^2 is to be not less than given by the following formulae:

$0,4d^3$ for the web adjacent to the bearing

$0,75d^3$ for intermediate webs

= where:

B = breadth of web, in mm

d = minimum diameter of crankshaft as required by *Vol 2, Pt 7, Ch 3, 12.4 Design and construction 12.4.2*, in mm

t = axial thickness of web, which is to be not less than 0,45*d* for the web adjacent to the bearing, or 0,60*d* for intermediate webs, in mm.

12.4.5 Fillets at the junction of crankwebs with crankpins or journals are to be machined to a radius not less than 0,05*d*. Smaller fillets, but of a radius not less than 0,025*d*, may be used, provided the diameter of the crankpin or journal is not less than *cd*:

= where:

c = $1,1 - 2\dfrac{r}{d}$ but to be taken as not less than 1,0

d = minimum diameter of crankshaft as required by *Vol 2, Pt 2, Ch 1, 8.5 Lubricating oil systems*, in mm

r = fillet radius, in mm.

12.4.6 Fillets and oil holes are to be rounded to an even contour and smooth finish.

12.4.7 An oil level sight glass or oil level indicator is to be fitted to the crankcase.

12.4.8 The crankcases of compressors are to be designed to withstand a pressure equal to the maximum working pressure of the system.

12.4.9 Compressors with shaft power exceeding 500 kW are to have torsional vibration analysis determined in accordance with *Vol 2, Pt 5, Ch 1 Torsional Vibration* as applicable.

12.4.10 The cooler dimensions for sea-water cooled stage air coolers are to be based on an inlet temperature of not less than 32°C. Where fresh water cooling is used, the cooling water inlet temperature is not to be greater than 40°C.

12.4.11 The cooler dimensions for air cooled stage air coolers are to be based on an air temperature of not less than 45°C.

12.4.12 The piping to and from the air compressor is to be arranged to prevent condensation from entering the cylinders.

12.5 Testing

12.5.1 Air compressors components are to be tested as indicated in *Table 1.3.1 Test and certification requirements for engine components*.

12.6 Safety arrangements and monitoring

12.6.1 Air compressors are to be arranged and located so as to minimise the intake of air contaminated by oil or water.

12.6.2 Where one compressor stage comprises several cylinders which can be shut off individually, each cylinder shall be equipped with a safety valve and a pressure gauge.

12.6.3 After the final stage, all air compressors are to be equipped with a water trap and after cooler. The water traps, after coolers and the compressed air spaces between the stages are to be provided with discharge devices at their lowest points.

12.6.4 Each compressor stage shall be fitted with a suitable pressure gauge, the scale of which must indicate the relevant maximum permissible working pressure.

12.7 Crankcase relief valves

12.7.1 In compressors having cylinders not exceeding 200 mm bore or having a crankcase gross volume not exceeding 0,6 m^3, crankcase relief valves may be omitted.

12.7.2 Crankcases are to be provided with lightweight spring-loaded valves or other quick-acting and self-closing devices to relieve the crankcases of pressure in the event of an internal explosion and to prevent any inrush of air thereafter. The valves are to be designed and constructed to open quickly and be fully open at a pressure not greater than 0,2 bar.

12.7.3 The valve lids are to be made of ductile material capable of withstanding the shock of contact with stoppers at the full open position.

12.7.4 Each valve is to be fitted with a flame arrester that permits flow for crankcase pressure relief and prevents the passage of flame following a crankcase explosion.

12.7.5 The valves are to be provided with a copy of the manufacturer's installation and maintenance manual for the size and type of valve being supplied. The manual is to contain the following information:

(a) Description of valve with details of function and design limits;
(b) Copy of type test certification;
(c) Installation instructions;
(d) Maintenance and in-service instructions to include testing and renewal of any sealing arrangements;
(e) Actions required after a crankcase explosion.

12.7.6 A copy of the installation and maintenance manual required by *Vol 2, Pt 7, Ch 3, 12.7 Crankcase relief valves 12.7.3* is to be provided on board the ship.

12.7.7 Plans showing details and arrangements of the crankcase relief valves are to be submitted for approval, *see Pt 2, Ch 1, 2.1* and *Vol 2, Pt 3, Ch 2, 5 Control and monitoring*.

12.7.8 The valves are to be provided with suitable markings that include the following information:

(a) Name and address of manufacturer;
(b) Designation and size;
(c) Month/Year of manufacture;
(d) Approved installation orientation.

12.8 Number of crankcase relief valves

12.8.1 In compressors having cylinders exceeding 200 mm but not exceeding 250 mm bore, at least two relief valves are to be fitted. Where more than one relief valve is required, the valves are to be located at or near the ends of the crankcase.

12.8.2 In compressors having cylinders exceeding 250 mm but not exceeding 300 mm bore, at least one relief valve is to be fitted in way of each alternate crank throw with a minimum of two valves. For compressors having 3, 5, 7, 9, etc. crank throws, the number of relief valves is not to be less than 2, 3, 4, 5, etc. respectively.

12.8.3 In compressors having cylinders exceeding 300 mm bore, at least one valve is to be fitted in way of each main crank throw.

12.8.4 Additional relief valves are to be fitted for separate spaces on the crankcase, such as gear or chain cases, when the gross volume of such spaces exceeds 0,6 m^3.

12.9 Size of crankcase relief valves

12.9.1 The combined free area of the crankcase relief valves fitted on a compressor is to be not less than 115 cm^2/m^3 based on the volume of the crankcase.

12.9.2 The free area of each relief valve is to be not less than 45 cm^2.

12.9.3 The free area of the relief valve is the minimum flow area at any section through the valve when the valve is fully open.

12.9.4 In determining the volume of the crankcase for the purpose of calculating the combined free area of the crankcase relief valves, the volume of the stationary parts within the crankcase may be deducted from the total internal volume of the crankcase.

12.10 Vent pipes

12.10.1 Where crankcase vent or breather pipes are fitted, they are to be made as small as practicable and/or as long as possible to minimise the inrush of air after an explosion.

12.11 Dead ship condition starting arrangements

12.11.1 Means are to be provided to ensure that machinery can be brought into operation from the dead ship condition without external aid.

12.11.2 Dead ship condition for the purpose of *Vol 2, Pt 7, Ch 3, 12.11 Dead ship condition starting arrangements 12.11.1* is to be understood to mean a condition under which the main propulsion plant, boilers and auxiliaries are not in operation. In restoring propulsion, no stored energy for starting and operating the propulsion plant is assumed to be available. Additionally, neither the main source of electrical power nor other essential auxiliaries is assumed to be available for starting and operating the propulsion plant.

12.11.3 Dead ship condition starting shall be possible in all ambient operating conditions, *see Vol 2, Pt 1, Ch 3, 4.5 Ambient operating conditions*.

12.11.4 Where the emergency source of power is an emergency generator which fully complies with the requirements of *Vol 2, Pt 9, Ch 2 Electrical Power Generator and Energy Storage* of the Rules, this generator may be used for restoring operation of the main propulsion plant, boilers and auxiliaries where any power supplies necessary for engine operation are also protected to a similar level as the starting arrangements.

12.11.5 Where there is no emergency generator installed or an emergency generator does not comply with *Vol 2, Pt 9, Ch 2 Electrical Power Generator and Energy Storage* of the Rules, the arrangements for bringing main and auxiliary machinery into operation are to be such that the initial charge of starting air or initial electrical power and any power supplies for engine operation can be developed on board ship without external aid. If for this purpose an emergency air compressor or an electric generator is required, these units are to be powered by a hand-starting oil engine or a hand-operated compressor. The arrangements for bringing main and auxiliary machinery into operation are to have capacity such that the starting energy and any power supplies for engine operation are available within 30 minutes of a dead ship condition.

12.11.6 The requirements for battery installations are given in *Vol 2, Pt 9, Ch 2 Electrical Power Generator and Energy Storage*.

12.12 Air receivers

12.12.1 Where the main engine is arranged for air starting, the total air receiver capacity is to be sufficient to provide without replenishment, not less than 12 consecutive starts of the main engine, alternating between ahead and astern if of the reversible type and not less than six consecutive starts if of the non-reversible type. At least two air receivers of approximately equal capacity are to be provided. For scantlings and fittings of air receivers, *see Vol 2, Pt 8, Ch 2 Other Pressure Vessels*.

12.12.2 For multi-engine installations, where more than one engine is driving each propulsion shaft line, the following requirements apply:

(a) Twin engine installations driving fixed pitch propeller, where one of the engines can be reversed, six consecutive starts per engine are required.
(b) For all other types of multi-engine installations three consecutive starts per engine are required.

12.12.3 Each air receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

12.12.4 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C.

12.12.5 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves and not fusible plugs.

Section 1
General requirements

1.1 Application

1.1.1 This Chapter covers the requirements for piping systems and arrangements in naval ships for bunkering, storing and distribution of fuel for aircraft/helicopters and diesel engined vehicles that are part of the ship's operational equipment.

1.1.2 In addition to the requirements detailed in this Chapter, the requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements* and *Vol 2, Pt 7, Ch 2, 1 General requirements*, *Vol 2, Pt 7, Ch 2, 2 Construction and installation* and *Vol 2, Pt 7, Ch 2, 10 Air, overflow and sounding pipes* are to be complied with where applicable.

1.1.3 The requirements of *Vol 2, Pt 7, Ch 2, 3 Drainage of compartments, other than machinery spaces* are also to be complied with, so far as they are applicable for the drainage of tanks, oily bilges and cofferdams, etc.

1.1.4 The requirements address refuelling systems where the flash point of the fuel is:

(a) not less than 60ºC (closed-cup test);
(b) less than 60ºC (closed-cup test).

1.1.5 The requirements of the Naval Administration and standards forNATO interoperability, are to be specified by the Owner.

1.1.6 Electrical arrangements are to comply with *Vol 2, Pt 9 Electrotechnical Systems* as applicable. Attention is drawn to *Vol 2, Pt 9, Ch 5 Hazardous Areas* where it is intended to carry fuel with a flash point not exceeding 60ºC.

1.2 Documentation required for design review

1.2.1 The following plans and particulars are to be submitted for approval:

- Description of fuel with statement of minimum flash point (closed-cup test).
- Arrangement of fuel storage and piping.
- Storage tanks not forming part of the ship's structure.
- Arrangements for drainage, ventilation and sounding of spaces adjacent to storage tanks where the flash point is less than 60º C.
- Details of pumping units.
- Arrangements for testing and increasing the flash point of low flash fuel from aircraft/helicopters for transfer into the ship's storage system.
- Arrangements for gas analysing arrangements required by *Vol 2, Pt 7, Ch 4, 3.1 General 3.1.5*.
- Arrangements for stripping water from storage tanks.
- Arrangements for emergency cross connections between aircraft/helicopter and ship's fuel systems.

1.2.2 **System Design Description**. A System Design Description is to be submitted for information, *see Vol 2, Pt 1, Ch 3, 3.5 System design description*.

1.2.3 **Operating manuals**. Operating manuals are to be provided on board and submitted for information where requested by LR. The manuals are to include the following information:

(a) Particulars and description of systems and arrangements for bunkering, fuelling and defuelling aircraft/ helicopters and vehicles.
(b) Operating instructions for the systems.

Section 2
Refuelling facilities

2.1 Fuel storage

2.1.1 When it is intended to store fuel with a flash point less than 60ºC, the requirements of *Vol 2, Pt 7, Ch 4, 2.1 Fuel storage 2.1.2* to *Vol 2, Pt 7, Ch 4, 2.1 Fuel storage 2.1.13* are to be complied with.

2.1.2 Storage tanks can be integral tanks or independent tanks and shall be located in a designated area. Tanks shall be segregated from accommodation, service and machinery spaces by provision of a cofferdam, *see Vol 2, Pt 7, Ch 4, 2.1 Fuel storage 2.1.10*.

2.1.3 Where independent fuel tanks in accordance with the requirements of *Vol 2, Pt 7, Ch 4, 2.2 Independent fuel oil tanks* are fitted, the compartment is to comply with the requirements of *Vol 2, Pt 9, Ch 5 Hazardous Areas* for hazardous zones, ventilation and access arrangements.

2.1.4 The storage and handling area is to be permanently marked. Instructions for filling fuel are to be posted in the vicinity of the filling area.

2.1.5 Storage tanks are to be protected from aircraft/ helicopter crashes, mechanical damage, solar radiation and high temperatures as a result of a fire occurring in an adjacent area. Where applicable, storage tanks are also to be protected from radar and HF radio effects.

2.1.6 Storage tanks are to be of an approved construction and attention is to be given to inspection procedures, mounting and securing arrangements and electrical bonding of tanks and fuel transfer system. The internal surfaces of steel tanks are to be suitably coated with impervious paint to prevent corrosion. The coating is to comply with *Vol 2, Pt 7, Ch 4, 2.6 Fuel contamination 2.6.1*. Independent fuel oil tanks are to comply with the requirements of *Vol 2, Pt 7, Ch 4, 2.2 Independent fuel oil tanks*. Transportable tanks shall be specially designed for their intended use and equipped with suitable fittings, lifting and fixing arrangements and earthing, and should comply with the relevant Codes for the transportation of dangerous goods in ships.

2.1.7 Tank ventilation pipes are to be fitted with an approved type of vent head with pressure-vacuum valve and flame arrester. The vent outlet is to be located in a safe position away from accommodation spaces, ventilation intakes and equipment that may constitute an ignition hazard.

2.1.8 Fuel storage and handling areas are to be provided with collection trays of suitable capacity for containing leakage from tanks, pump units and other equipment that requires opening up for maintenance, and for draining any such leakage to a tank or container located in a safe area. For tanks forming an integral part of the ship's structure, cofferdams are to be provided as necessary to contain leakage and prevent contamination of the fuel.

2.1.9 Tanks are to be provided with a level indicator that is fitted through the top of the tank and certified for installation in the appropriate hazardous zone. *See Vol 2, Pt 10, Ch 1 Ergonomics*

2.1.10 Cofferdams are to be provided between tanks and containing sources of ignition.

2.1.11 The cofferdam is to be provided with permanently fitted gas detectors, and a permanent ventilation system.

2.1.12 Drainage of the cofferdam space is to be entirely separate from the machinery space drainage arrangements.

2.1.13 The air pipe for the cofferdam space is to be led to the open in a safe space and fitted with an approved air pipe head having a wire gauze diaphragm of incorrodible material.

2.1.14 Where it is intended to store fuel having a flash point not less than 60ºC, the arrangements are to be in accordance with *Vol 2, Pt 7, Ch 4, 2.1 Fuel storage 2.1.4*, *Vol 2, Pt 7, Ch 4, 2.1 Fuel storage 2.1.5*, *Vol 2, Pt 7, Ch 4, 2.1 Fuel storage 2.1.6*, *Vol 2, Pt 7, Ch 4, 2.1 Fuel storage 2.1.8* and with the applicable requirements of *Vol 2, Pt 7, Ch 2 Ship Piping System* and *Vol 2, Pt 7, Ch 3 Machinery Piping Systems*.

2.1.15 In addition to the particular requirements relating to the storage of fuel having flash points greater or less than 60ºC as identified in *Vol 2, Pt 7, Ch 4, 2.1 Fuel storage 2.1.1* and *Vol 2, Pt 7, Ch 4, 2.1 Fuel storage 2.1.14*, the requirements of *Vol 2, Pt 7, Ch 4, 2.1 Fuel storage 2.1.16* to *Vol 2, Pt 7, Ch 4, 2.1 Fuel storage 2.1.20* are also to be complied with for all fuels.

2.1.16 Storage tanks are to be provided with stripping arrangements to facilitate the removal of water.

2.1.17 A separate tank is to be provided to collect stripping and system drains and is to be arranged such that it can be drained to a fuel recovery tank.

2.1.18 Means are to be provided to eliminate the possibility of overflow from storage tanks into spaces where there are sources of ignition and to safeguard against overflow from the tanks through the air pipes. High level alarm arrangements are to be provided to indicate when fuel storage tanks have been filled in excess of maximum operating levels. In addition, low level alarm arrangements are to be provided for storage tanks capable of supplying fuel to refuelling systems.

2.1.19 The use of water compensated fuel tanks for fuel supply to aircraft and helicopters is not permitted. Wherever practicable they are to be avoided for fuel supply to diesel engined vehicles. Attention is drawn to regulations that may be specified by the Naval Administration in connection with the *International Convention for the Prevention of Pollution of the Sea by Oil, 1973/78*. Where ship design considerations require the use of such tanks, the requirements of *Vol 2, Pt 7, Ch 3, 4.18 Water compensated fuel oil tanks* are applicable

2.1.20 *See Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding 2.4.11* for requirements for control of static electricity.

2.1.21 Where it is intended to temporarily carry fuel with a flash point not exceeding 60ºC, this shall be stored in a designated area which shall comply with *Vol 2, Pt 7, Ch 4, 2.1 Fuel storage 2.1.3*.

2.2 Independent fuel oil tanks

2.2.1 Where separate fuel oil tanks are permitted, their construction is to be in accordance with the requirements of *Vol 2, Pt 7, Ch 4, 2.2 Independent fuel oil tanks 2.2.2*, *see also* SOLAS 1974 as amended *Regulation 4 - Probability of ignition*.

2.2.2 In general, the minimum thickness of the plating of independent fuel oil tanks, where they do not form part of the structure of the ship, is to be 5 mm, but in the case of very small tanks, less than 500 litres, the minimum thickness may be 3 mm.

2.2.3 For rectangular steel tanks of welded construction, the plate thicknesses are to be not less than those indicated in *Table 4.2.1 Plate thickness of independent fuel oil tanks*. The stiffeners are to be of approved dimensions.

2.2.4 The dimension given in *Table 4.2.1 Plate thickness of independent fuel oil tanks*for the breadth of the panel is the maximum distance allowable between continuous lines of support, which may be stiffeners, washplates or the boundary of the tank.

Table 4.2.1 Plate thickness of independent fuel oil tanks

Thickness of plate, in mm	Head of bottom of tank to top of overflow pipe, in metres				
	2,5	3,0	3,7	4,3	4,9
	Breadth of panel, in mm				
5	585	525			
6	725	645	590		
7	860	770	700	650	
8	1000	900	820	750	700
10	1280	1140	1040	960	900

2.2.5 Where necessary, stiffeners are to be provided, and if the length of the stiffener exceeds twice the breadth of the panel, transverse stiffeners are also to be fitted, or, alternatively, tie bars are to be provided between stiffeners on opposite sides of the tank.

2.2.6 On completion, the tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

2.2.7 Where independent tanks are for the storage of fuel with a flash point below 60°C, provisions are to be made for the measurement of fuel oil temperature at the pump suction pipe.

2.3 Fuel pumping and filling

2.3.1 The pumping and filling arrangements are to comply with the requirements of *Vol 2, Pt 7, Ch 4, 2.3 Fuel pumping and filling 2.3.2*.

2.3.2 Tank outlet valves and filling valves located below the top of the tank are to be mounted directly onto the tank and are to be capable of being closed from a remote location outside the compartment in the event of a fire in the compartment. Ball valves are to be of the stainless steel, anti-static, fire tested type.

2.3.3 The pumping unit is to be arranged to be connected to only one tank at a time. Pipes between the tanks and the pumping unit are to be of stainless steel or equivalent material, or flexible hoses of an approved type, fire-tested to an acceptable National Standard. Such pipes or hoses are to be protected from mechanical damage and be as short as possible. Where a flexible hose is used to connect the pumping unit to a tank, the hose connection is to be of the quick-disconnect, self-closing type.

2.3.4 Fuel oil bunkering system(s) for ship's propulsion and auxiliary engines are to be separate from the refueling systems for aircraft. Provision is to be made for an emergency cross connection to enable:

(a) In an emergency, the supply of propulsion/auxiliary machinery fuel oil to aircraft/helicopters/vehicle refueling systems.
(b) For operational reasons, the transfer and addition of aircraft fuel to the fuel oil storage system for the ship's propulsion/auxiliary engines.

The emergency cross connections are to incorporate an isolating valve on each system with a portable connection between them and be clearly marked and arranged to prevent inadvertent use.

2.3.5 Pumping units are to be capable of being controlled from the fuel station and from a position remote from the fuel station.

2.3.6 Pumping units shall incorporate a device to prevent over-pressurisation of the filling hose.

2.3.7 Arrangements for circulation of fuel through filter units, fuel metering and fuel sampling are to be provided. To allow circulation of fuel, each tank is to be provided with suitable high and low suction arrangements.

2.3.8 Filling arrangements for tanks are to be through closed piping systems with outlet ends configured to reduce turbulence and foaming of the fuel.

2.3.9 The locker housing equipment associated with fuel filling is to be well ventilated and drained.

2.3.10 Fuel piping systems are to be designed to limit the maximum flow rate to 7.0 m/s to reduce the possibility of the build up of static electricity.

2.3.11 Suitable filtration arrangements are to be provided to reduce the level of water and particulate contamination of the fuel to within the limits specified by the Owner.

2.3.12 Fuelling and defuelling stations are to be located away from, or sheltered from, radar and HF radio hazards. *See also Vol 2, Pt 1, Ch 3, 4.18 Electromagnetic hazards*.

2.3.13 Pipe systems designed for portable hose connections are to be provided with an isolating valve and blanking arrangement at each connection. Non-return valves are to be provided at connections where necessary to prevent back flow of fluids into systems and tanks where this could affect the integrity of the system or spaces.

2.3.14 All piping systems intended for fuel having a flash point less than 60ºC are to be located clear of accommodation spaces, escape routes, embarkation stations and ventilation openings and are not to pass through category A machinery spaces.

2.3.15 Means are to be provided for keeping deck spills away from accommodation and service areas. This may be accomplished by means of a 300 mm coaming extending from side to side. Special consideration will be given to the arrangements associated with stern loading.

2.3.16 Drip trays for collecting replenishment oil residues in pipelines and hoses are to be provided beneath pipe and hose connections in the manifold area.

2.4 Refuelling aircraft/helicopters

2.4.1 Service tanks for storing ready use fuel are to be provided with test facilities to determine fuel quality and stripping arrangements for removal of any water found. The tanks are to be provided with sloping bottoms to assist in stripping water.

2.4.2 Arrangements are to be provided for fuel to be passed through suitable filtration/water absorption equipment immediately prior to embarking fuel onto an aircraft. This equipment should be as near as practicable to the aircraft.

2.4.3 Refuelling and defuelling hoses are to be of an approved type. Hoses for refuelling are to include an automatic shut-off facility at the aircraft or vehicle end. A hose end pressure controller is also to be provided for fuelling hoses to prevent the possibility of the aircraft/helicopter fuel tanks being subject to excessive pressure.

2.4.4 Provision is to be made to earth the aircraft of static electricity before commencing and during any refuelling/ defuelling procedure.

2.4.5 To allow through flushing, the pipe system to refuelling stations is to include shut off valves and a return pipe system to the storage or recovery tanks.

2.5 Defuelling

2.5.1 Arrangements are to be made to ensure that only fuel having a flash point equal to or greater than the flash point for which the ship has been designed and approved for is discharged into the ship's fuel storage system. Arrangements and equipment are to be provided to ensure that if defuelling of aircraft/helicopters carrying fuel having a flash point less than 60°C is required, the fuel flash point is increased to a figure above 60°C before discharge into the ship's storage system. Fuel from aircraft/ helicopters may also be contaminated and to provide segregation before discharge to the ship's storage system, a separate recovery tank for handling this fuel is to be provided. The capacity of the recovery tank is to be sufficient to safely handle the fuel from an aircraft/ helicopter and is to be identified in the System Design Description required by *Vol 2, Pt 7, Ch 4, 1.2 Documentation required for design review 1.2.2*.

2.5.2 Hoses used for defuelling are to comply with *Vol 2, Pt 7, Ch 4, 2.4 Refuelling aircraft/helicopters 2.4.3*.

2.6 Fuel contamination

2.6.1 Materials and/or their surface treatment used for the storage and distribution of fuel are to be selected such that they do not introduce contamination or modify the properties of the fuel. The use of copper or zinc compounds in fuel piping systems where they may come into contact with the fuel is not permitted. Copper-nickel materials are permissible but are to be limited to positions after the filtration/water absorption equipment required by *Vol 2, Pt 7, Ch 4, 2.4 Refuelling aircraft/helicopters 2.4.2*.

2.6.2 The location and arrangement of air pipes for fuel tanks are to be such that in the event of a broken vent pipe, this does not directly lead to ingress of sea-water or rain water.

■ *Section 3*
Pump rooms

3.1 General

3.1.1 Where it is intended to install fuel transfer pumps for handling fuel with a flash point less than 60ºC in a separate compartment, the requirements of *Vol 2, Pt 7, Ch 4, 3.1 General 3.1.2* to *Vol 2, Pt 7, Ch 4, 3.1 General 3.1.5*, *Vol 2, Pt 7, Ch 4, 3.2 Pump room ventilation* and *Vol 2, Pt 7, Ch 4, 3.3 Non-sparking fans for hazardous areas* are to be complied with.

3.1.2 The pump rooms are to be totally enclosed and are to have no direct communication, through e.g. bilge piping systems and ventilation systems, with machinery spaces.

3.1.3 Pump rooms are to be situated adjacent to the fuel storage tanks and are to be provided with ready means of access from the open deck.

3.1.4 Alarms and safety arrangements are to be provided as indicated in *Vol 2, Pt 7, Ch 4, 3.1 General 3.1.5*and *Table 4.3.1 Alarms*. These requirements are applicable to pump rooms where pumps for fuels, such as fuel pumps and stripping pumps are provided and not for pump rooms intended solely for ballast transfer.

Table 4.3.1 Alarms

Item	Alarm	Note
Bulkhead gland temperature	High *See* Note 1	Any machinery item
Pump bearing and casing temperature	High *See* Note 1	Any machinery item
Bilge level	High	—

Hydrocarbon concentration	High *See* Note 2	> 10% LEL
Note 1. The alarm signal is to trigger continuous visual and audible alarms in the pump room or the pump control station. **Note** 2. This alarm signal is to trigger a continuous audible and visual alarm in the pump room, pump control station and machinery control room.		

3.1.5 A system for continuously monitoring the concentrations of hydrocarbon gases within the pump room is to be fitted. Monitoring points are to be located in positions where potentially dangerous concentrations may be readily detected. Gas analysing units with non-safe-type measuring equipment may be located outside dangerous areas (e.g. in fuel oil pumping control room, navigation bridge or engine room when mounted on the adjacent bulkhead) provided that:

(a) sampling lines do not pass through gas safe spaces, except where permitted by *Vol 2, Pt 7, Ch 4, 3.1 General 3.1.5*;
(b) the gas sampling pipes are fitted with flame arresters. Sample gas is to be led to the atmosphere with outlets arranged in a safe location, in the open atmosphere;
(c) bulkhead penetrations of sample pipes between safe and dangerous areas are of an approved type. A manual isolating valve is to be fitted in each of the sampling lines at the bulkhead in the safe area;
(d) the gas detection equipment including sampling piping, sampling pumps, solenoid valves and analyzing units, are located in a fully enclosed steel cabinet, with a gasketed door, monitored by its own sampling point. At gas concentrations above 30 per cent LEL inside the steel cabinet, the entire gas-analyzing unit is to be automatically shut-down; and
(e) where the cabinet cannot be arranged on the bulkhead, sample pipes are to be of steel or other equivalent material and without detachable connections, except for the connection points for isolating valves at the bulkhead and analyzing units. The sample pipes are to be led by their shortest route.

Sequential sampling is acceptable as long as it is dedicated for the pump room only, including exhaust ducts, and the detection equipment is capable of monitoring from each sampling head location at intervals not exceeding 30 minutes.

3.1.6 Where the flash point of the fuel is not less than 60ºC, the arrangements are to comply with the requirements applicable to machinery spaces, *see Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*.

3.2 Pump room ventilation

3.2.1 Fuel pump rooms and other closed spaces which contain fuel handling equipment, and to which regular access is required during cargo handling operations, are to be provided with permanent ventilation systems of the mechanical extraction type.

3.2.2 The ventilation system is to be capable of being operated from outside the compartment being ventilated and a notice to be fixed near the entrance stating that no person is to enter the space until the ventilation system has been in operation for at least 15 minutes.

3.2.3 The ventilation systems are to be capable of 20 air changes per hour, based on the gross volume of the pump room or space.

3.2.4 The ventilation ducting is to be arranged to permit extraction from the vicinity of the pump room bilges, immediately above the transverse floor plates or bottom longitudinals. An emergency intake is also to be arranged in the ducting at a height of 2 m above the pump room lower platform and is to be provided with a damper capable of being opened or closed from the weather deck and lower platform level. An arrangement involving a specific ratio of areas of upper emergency and lower main ventilation openings, which can be shown to result in at least the required number of air changes through the lower inlets, can be accepted without the use of dampers. When the lower inlets are sealed off, owing to flooding of the bilges, then at least 75 per cent of the required number of air changes is to be obtainable through the upper inlets. Means are to be provided to ensure the free flow of gases through the lower platform to the duct intakes.

3.2.5 Protection screens of not more than 13 mm square mesh are to be fitted in outside openings of ventilation ducts, and ventilation intakes are to be so arranged as to minimise the possibility of re-cycling hazardous vapours from any ventilation discharge opening. Vent exits are to be arranged to discharge upwards.

3.2.6 The vent exits from pump rooms are to discharge at least 3 m above deck, and from the nearest air intakes or openings to accommodation and enclosed working spaces, and from possible sources of ignition.

3.2.7 The ventilation is to be interlocked to the lighting system (except emergency lighting) such that the pump room lighting may only come on when the ventilation is in operation. Failure of the ventilation system is not to cause the lighting to go out and failure of the lighting system is not to cause loss of the ventilation system.

3.3 Non-sparking fans for hazardous areas

3.3.1 The air gap between impeller and housing of the fan is to be not less than 0,1 of the impeller shaft bearing diameter or 2 mm whichever is the larger, subject also to compliance with *Vol 2, Pt 7, Ch 4, 3.3 Non-sparking fans for hazardous areas 3.3.2*. Generally, however, the air gap need be no more than 13 mm.

3.3.2 The following combinations of materials are permissible for the impeller and the housing in way of the impeller:

(a) Impellers and/or housings of non-metallic material, due regard being paid to the elimination of static electricity.
(b) Impellers and housings of non-ferrous metals.
(c) Impellers and housings of austenitic stainless steel.
(d) Impellers of aluminium alloys or magnesium alloys and a ferrous housing provided that a ring of suitable thickness of non-ferrous material is fitted in way of the impeller.
(e) Any combination of ferrous impellers and housings with not less than 13 mm tip clearance.
(f) Any combination of materials for the impeller and housing which are demonstrated as being spark proof by appropriate rubbing tests.

3.3.3 The following combinations of materials for impellers and housing are not considered spark proof and are not permitted:

(a) Impellers of an aluminium alloy or magnesium alloy and a ferrous housing, irrespective of tip clearance.
(b) Impellers of a ferrous material and housings made of an aluminium alloy, irrespective of tip clearance.
(c) Any combination of ferrous impeller and housing with less than 13 mm tip clearance, other than permitted by *Vol 2, Pt 7, Ch 4, 3.3 Non-sparking fans for hazardous areas 3.3.2*.

3.3.4 Electrostatic charges both in the rotating body and the casing are to be prevented by the use of antistatic materials (i.e. materials having an electrical resistance between 5×10^4 ohms and 10^8 ohms), or special means are to be provided to avoid dangerous electrical charges on the surface of the material.

3.3.5 Type tests on the complete fan are to be carried out to the Surveyor's satisfaction.

3.3.6 Protection screens of not more than 13 mm square mesh are to be fitted in the inlet and outlet of ventilation ducts to prevent the entry of objects into the fan housing.

3.3.7 The installation of the ventilation units on board is to be such as to ensure the safe bonding to the hull of the units themselves.

■ *Section 1*
General requirements

1.1 General

1.1.1 This Chapter states the requirements for piping systems installed in naval ships for the operation and functioning of equipment installed for purposes relating to the Ship Type.

1.1.2 The requirements in this Chapter cover piping and control systems necessary for ships that have Ship Type piping systems and equipment configured such that, in the event of a single failure or damage in any part of a piping system, the ship will continue to retain availability of services relating to the Ship Type.

1.2 Scope

1.2.1 Ship Type piping systems included in this Chapter are:

(a) Chilled water systems used for:
- (i) Weapons and electrical equipment cooling.
- (ii) Air conditioning systems.

(b) High pressure compressed air systems used for:
- (i) Filling breathing air bottles used for diving and firefighting.
- (ii) Starting air for diesel engines and gas turbines.
- (iii) Machinery shaft brakes.
- (iv) Weapon handling and control.
- (v) Supply to low pressure compressed air systems through reducing stations.

(c) Low pressure compressed air systems used for:
- (i) Control systems for machinery and weapons.
- (ii) Air tools.
- (iii) Valve actuation.
- (iv) General supplies to seals, filters, sewage plant, etc.

(d) High pressure sea-water systems used for:
- (i) Fire-fighting and boundary cooling.

(ii) Pre-wetting.
(iii) Bilge and dewatering eductors.
(iv) Emergency cooling of machinery.
(v) Machinery space ventilation coolers in closedown operation.

(e) Hydraulic power actuating systems used for:

(i) Remote controlled equipment (doors, valves).
(ii) Platform equipment (lifts, hoists).
(iii) Machinery systems (stabilisers, hydraulic motors).

1.2.2 Other systems defined as Ship Type category engineering systems, *see Vol 2, Pt 1, Ch 1, 3.1 Categories 3.1.3*, as specified.

1.3 Documentation required for design review

1.3.1 In addition to the information required by *Vol 2, Pt 7, Ch 1, 2.1 Documentation required for design review 2.1.1*, three copies of the plans and information stated in *Vol 2, Pt 7, Ch 5, 1.3 Documentation required for design review 1.3.2* to *Vol 2, Pt 7, Ch 5, 1.3 Documentation required for design review 1.3.7*are to be submitted to Lloyd's Register (hereinafter referred to as 'LR') as applicable.

1.3.2 **System Design Description**. A System Design Description of each Ship Type piping system, *see Vol 2, Pt 1, Ch 3, 3.5 System design description*.

1.3.3 **Systems**. Plans in diagrammatic form showing piping arrangements, control systems and safeguards and electrical systems for each Ship Type piping system covered by this Chapter. The capacities of pumps and compressors are to be included. For chilled water systems, heat load calculations or heat balance sheets and capacity tables with condensing temperatures covering the operating range of the refrigeration compressors are also to be included. The tables are to be representative of the compressors operating at the design revolutions per minute with the nominated refrigerant.

1.3.4 **Compartments**. Plans showing the general arrangement of compartments, together with a description of the Ship Type system(s) installed and the electrical power supply systems. The plans are to indicate segregation and access arrangements for compartments and associated control rooms/stations.

1.3.5 **Risk Assessment (RA)**. For Ship Type piping systems with associated electrical power supplies and control systems, the RA report is to address the requirements in *Vol 2, Pt 7, Ch 5, 5 Risk Assessment (RA)*.

1.3.6 **Testing and trials procedures**. A schedule of testing and trials to demonstrate that systems are capable of operating as described in *Vol 2, Pt 7, Ch 5, 3 System arrangements*. Testing and trials procedures are to comply with *Vol 2, Pt 7, Ch 5, 6.3 Trials 6.3.1*. In addition, any testing programme that may be necessary to prove the conclusions of the RA, *see Vol 2, Pt 7, Ch 5, 6.3 Trials 6.3.2*.

1.3.7 **Operating Manuals**. Operating Manuals are to be provided on board and submitted for information where requested by LR. The Manuals are to include the following information:

(a) Particulars and a description of each system.
(b) Operating instructions for all systems.
(c) Procedures for dealing with the situations identified in the RA report.

1.4 Use of alternative standards

1.4.1 Where it is proposed to use arrangements different from those required by this Chapter and the arrangements are in accordance with an applicable National/International Standard, the use of such arrangements will be accepted by LR.

1.4.2 Where alternative design codes/standards are used, they are stated together with any assumptions made.

■ Section 2
Construction and installation

2.1 Materials

2.1.1 Pipes, valves and fittings are to be made of steel, ductile cast iron, copper, copper alloy, or other approved ductile material suitable for the intended purpose.

2.1.2 Where applicable, the materials are to comply with the requirements of *Vol 2, Pt 7, Ch 1, 4 Materials*.

2.1.3 Materials sensitive to heat, such as aluminium or plastics, are in general not to be used for Ship Type piping systems. Such materials are not in any event to be used in systems containing flammable liquids or sea-water where leakage or failure could result in fire or in the flooding of watertight compartments. *See Vol 2, Pt 7, Ch 1 Piping Design Requirements* for plastics pipes.

2.1.4 The selection of materials in piping systems is to recognise the following details:

(a) Fluids properties, pressures and temperatures.
(b) Location and configuration.
(c) Compatibility of materials.
(d) Fluid flow rates and static conditions.
(e) Minimising corrosion and erosion through life of system.
(f) System survey and maintenance requirements.

See Vol 2, Pt 7, Ch 1, 17 Guidance notes on metal pipes for water service for guidance notes on metal pipes for water services.

2.2 Pipe wall thickness

2.2.1 The minimum nominal wall thickness of steel, copper and copper alloy pipes is to be in accordance with *Vol 2, Pt 7, Ch 1 Piping Design Requirements*. Where refrigerant tubes are in tube bundles, special consideration will be given to the minimum thickness requirements recognising the inherent strength of tube bundles and the benefits of increased heat transfer properties of thin wall tubes.

2.2.2 Special consideration will be given to the wall thickness of pipes made of materials other than steel, copper and copper alloy.

2.3 Piping and equipment - Selection and installation

2.3.1 Air receivers and gas pressurised hydraulic accumulators are to be in accordance with *Vol 2, Pt 8, Ch 2 Other Pressure Vessels* or a recognised Code, where applicable. Materials used in the construction are to be manufactured and tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials).

2.3.2 Valves, flexible hose lengths, expansion pieces and pumps are to comply with the relevant requirements of *Vol 2, Pt 7, Ch 1, 12 Valves* to *Vol 2, Pt 7, Ch 1, 15 Pumps*. Equipment used in Ship Type piping systems is to be suitable for its intended purpose, and accordingly, wherever practicable, be selected from the *Lists of LR Type Approved Products* published by LR.

2.3.3 Pipes in piping systems are to be permanent pipes made with approved pipe connections to enable ready removal of valves, pumps, fittings and equipment. The pipes are to be efficiently secured in position to prevent chafing or lateral movement. The selection of pipe connections in refrigeration systems is to minimise the possibility of refrigerant leaks and the use of flared fittings in such systems is to be avoided.

2.3.4 Suitable means for expansion are to be made, where necessary, in each range of pipes.

2.3.5 Efficient protection is to be provided for all pipes situated where these are liable to mechanical damage.

2.3.6 All moving parts are to be provided with guards to minimise danger to personnel.

2.3.7 Piping systems that may contain low temperature refrigerant are to be thermally insulated to an extent that will minimise condensation of moisture. Chilled water pipes are to be provided with insulation for system efficiency.

2.4 Valves - Installation and control

2.4.1 Valves are to be fitted in places where they are at all times readily accessible.

2.4.2 All valves that are provided with remote control arrangements are to be arranged for local manual operation, independent of the remote operating mechanism. The local manual means of operation is to be readily accessible.

2.4.3 Relief valves are to be adjusted and bursting discs so selected that they relieve at a pressure not greater than the design pressure of the system. When satisfactorily adjusted, relief valves are to be protected against tampering or interference by wire with a lead seal or similar arrangement.

2.4.4 The related discharge capacity of pressure relief valves is to be determined in accordance with a recognised Standard or Code.

■ *Section 3*
System arrangements

3.1 Piping systems

3.1.1 Piping systems are to be arranged so that supply of services relating to the Ship Type will continue to be available in the event of a single failure or damage of a system or item of equipment.

3.1.2 The design of piping systems is to minimise vulnerability and provide capability for maximising recovery of supply to users. Factors to be considered include: redundancy, separation, protection, accessibility for repair, means of bridging breaches, number of pumps, alternate power supplies and use of portable pumps where appropriate.

3.1.3 The design of piping systems is to recognise operational and manning philosophy for the vessel and is to be declared in the System Design Description required by *Vol 2, Pt 7, Ch 5, 1.3 Documentation required for design review 1.3.2*.

3.1.4 The arrangement of equipment and systems is to ensure that failure or damage to a system will not cause immediate complete loss of the system. Systems are to be capable of accommodating progressive actions (manual and/or automatic) that will provide availability of supply to Mobility and/or Ship Type systems for agreed periods of time in the event of action damage.

3.1.5 In the event of multiple failure or damage to a piping system, arrangements are to be provided to enable the system to be reconfigured to supply essential services.

3.1.6 Accessible means of isolation are to be provided to isolate damaged areas to ensure that maximum system capability remains available after damage to the piping system.

3.1.7 Piping systems are in general to be capable of providing support to, or substituting for, a similar but damaged system.

3.1.8 Where a piping system has failed or been damaged, any resulting hazards are to be minimised.

3.1.9 All equipment fitted in piping systems is to be readily accessible to facilitate maintenance and survey. For this purpose, valves or cocks are to be interposed between items of equipment and the inlet and outlet pipes in order that any item of equipment may be shut off for opening up and overhauling.

3.1.10 Filter elements fitted in piping systems are to be capable of being cleaned and or changed without interruption of fluid flow. Filter elements fitted in refrigerant circuits are also to be arranged to minimise refrigerant leakage to atmosphere when being cleaned and/or changed. The arrangements for cleaning and changing filter elements are to include means of isolation and recovery of ozone depleting substances before opening up.

3.1.11 Pressure relief devices are to be mounted in such a way that it is not possible to isolate them from the part of the system which they are protecting except that, where duplicated, a changeover valve may be fitted that will allow either device to be isolated for maintenance purposes without it being possible to shut off the other device at the same time. Where arrangements are such that a relief valve can be removed from a common discharge line shared with another relief valve, provision is to be made to blank off the open connection to the discharge line, without compromising the safety of the system.

3.1.12 Relief discharge is to be led to a safe place. Discharge piping is to be designed to preclude ingress of water, dirt or debris that may cause the equipment to malfunction. Any common discharge system for relief valves is to be arranged to ensure that with all the relief valves open, the back pressure of the discharge system will not exceed 10% of the valve set pressure.

3.1.13 Sea-water valves and fittings are to comply with *Vol 2, Pt 7, Ch 2, 2.5 Ship-side valves and fittings (other than those on scuppers and sanitary discharges)*.

3.1.14 Piping system arrangements and associated equipment are to be capable of operating satisfactorily under the conditions shown in *Table 3.4.2 Inclinations* in Pt 1, Ch 3.

3.2 Electrical power supplies

3.2.1 The electrical engineering arrangements are to comply with *Vol 2, Pt 9 Electrotechnical Systems*.

3.2.2 The power supplies to electrical equipment in Ship Type systems are to be led from at least two independent sources that are capable of being connected by bus section switches.

3.2.3 In the event of the loss of one source of electrical supply, there is to be continuity of sufficient electrical power to supply the electrical equipment in Ship Type systems.

■ *Section 4*
Control arrangements

4.1 General

4.1.1 Equipment used in Ship Type piping systems is to be provided with local and remote control and monitoring arrangements.

4.1.2 The control, alarm and monitoring systems are to comply with *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*.

4.1.3 Where isolation of Mobility systems or Ship Type systems is to be carried out whether automatically or manually, indication of the status of isolation is to be provided at each control station.

4.1.4 Indication of the operational status of running and standby equipment is to be provided for all Ship Type piping systems at each control station.

4.1.5 Alarms are to be provided for compartments containing equipment for operation of Ship Type piping systems in the event of:

(a) A fire.
(b) A high bilge alarm level in any compartment that could be flooded by ingress of sea water and situated below the damage control deck. Irrespective of the assignment of the **UMS** notation, the bilge level detection system and arrangements for automatically pumping out bilge wells, if applicable, are to comply with *Vol 2, Pt 10, Ch 1, 6.5 Displays*.

4.1.6 Refrigeration compressors for chilled water systems are to be provided with the following instrumentation and automatic shutdowns:

(a) Indication of suction pressure (saturated temperature), including intermediate stage when applicable.
(b) Indication of discharge pressure (saturated temperature), including intermediate stage when applicable.
(c) Indication of lubricating oil pressure.
(d) Indication of cumulative running hours.
(e) Automatic shutdown in the event of low lubricating oil pressure.
(f) Automatic shutdown in the event of high discharge pressure which is to operate at a pressure in excess of normal operating pressure but not greater than 0,9 of the maximum working pressure.
(g) Automatic shutdown in the event of a low suction pressure.

4.1.7 Refrigerant compressors greater than 25kW for chilled water systems are to be provided with the following instrumentation in addition to that required by *Vol 2, Pt 7, Ch 5, 4.1 General 4.1.6*:

(a) Indication of lubricating oil temperature.
(b) Indication of cooling water outlet temperature.
(c) Indication of suction and discharge temperatures.

4.1.8 Air compressors are to be provided with the following instrumentation and automatic shutdowns:

(a) Indication of discharge pressure and temperature.
(b) Indication of lubricating oil pressure and temperature.
(c) Indication of cooling water outlet temperature where applicable.
(d) Indication of cumulative running hours.
(e) Automatic shutdown in the event of low lubricating oil pressure.

(f) Automatic shutdown in the event of high discharge pressure.

4.1.9 Alarms are to be initiated in the event of the following fault conditions with the refrigerant compressors for cooling water systems and air compressors:

(a) High discharge pressure.
(b) Low suction pressure (cooling compressors only).
(c) Low oil pressure.
(d) High discharge temperature.
(e) High oil temperature.
(f) Motor shutdown.

4.1.10 Chilled water systems are to be provided with the following alarms:

(a) Failure of condenser cooling water pumps.
(b) High condenser cooling water outlet temperature.
(c) Failure of air cooler fans associated with the operation of chilled water plant.
(d) High and low chilled water delivery temperatures.

4.1.11 All pumps are to be provided with an indication of discharge pressure, a low discharge pressure alarm and a motor shutdown alarm.

■ *Section 5*
Risk Assessment (RA)

5.1 General

5.1.1 A Risk Assessment in accordance with *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)* is to be carried out for piping systems, electrical power supplies and control systems to demonstrate that suitable risk mitigation has been achieved, for all normal and foreseeable abnormal conditions which could lead to a loss of all system capability.

5.1.2 The RA is to establish that the system retains a level of operational capability as defined in the System Design Description required by *Vol 2, Pt 7, Ch 5, 1.3 Documentation required for design review 1.3.2*, following failure or damage of pipework, an item of equipment or the loss of a compartment.

■ *Section 6*
Testing and trials

6.1 Testing

6.1.1 The requirements of the Rules relating to testing of pressure vessels, piping and related fittings including hydraulic testing are applicable. (*see Vol 2, Pt 8, Ch 2, 10 Hydraulic tests* and *Vol 2, Pt 7, Ch 1, 16 Testing*).

6.1.2 On completion, tanks and reservoirs for service and storage of system fluids are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

6.1.3 After installation on board, piping systems together with associated fittings that are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

6.1.4 Testing is to cover the following items:

(a) Verification of control, alarm, safety and where applicable, refrigerant detection systems.
(b) Tests simulating failure of selected components such as compressors, pumps and fans, to verify correct functioning of alarm and systems in service.
(c) Verification of accuracy, calibration and functioning of temperature control, monitoring and recording instrumentation for chilled water and associated refrigerant systems.

6.2 Type testing

6.2.1 Each type of pump and compressor unit is to be subjected to a type test that replicates the intended operating cycle/ environment as far as practicable, e.g. still air conditions and high/low ambient air temperatures. The type test is to be for a duration of not less than 100 hours, the test arrangements are to be such that the units may run in idling conditions, and at maximum delivery capacity at maximum working pressure. During the test, idling periods are to be alternated with periods at maximum delivery capacity at maximum working pressure. The passage from one condition to another should occur at least as quickly as may in service on board. During the whole test, no abnormal heating, excessive vibration or other irregularities are permitted. After the test, the unit is to be opened out and inspected. Type tests may be waived for units that have been proven to be reliable in marine service or that have been previously type tested with satisfactory certification and testing evidence.

6.3 Trials

6.3.1 Trials are to be carried out to demonstrate the capability of systems to meet System Design Descriptions. The trials are as far as practicable to be representative of the actual conditions to be encountered in service.

6.3.2 Where the Risk Assessment (RA) report has identified the need to prove the conclusions, testing and trials are to be carried out as necessary to investigate the following:

(a) The effect of a specific component failure or damage situation.
(b) The effectiveness of automatic/manual isolation systems.
(c) The effectiveness of reconfiguration arrangements.
(d) The behaviour of any interlocks that may inhibit operation of other systems.

■ *Section 7*
Chilled water systems

7.1 General

7.1.1 The requirements in this Section are additional to those contained in *Vol 2, Pt 7, Ch 5, 2 Construction and installation* of this Chapter.

7.1.2 Chilled water systems are to produce and distribute treated demineralised chilled water throughout the ship to provide cooling to heat exchangers and other direct cooled equipment that may include air conditioning and weapons systems.

7.1.3 The refrigeration plant and chilled water system is to be designed to be capable of continuously extracting at least 115% of the maximum heat load duty when operating at the conditions stated in the System Design Description required by *Vol 2, Pt 7, Ch 5, 1.3 Documentation required for design review 1.3.2*.

7.1.4 The demineralised water used in chilled water distribution systems is to be in accordance with the system designer's specification that typically would include the following limitations:

- Conductivity: <4,5 micromhs/cm^3
- Dissolved solids: Zero
- Alkalinity: pH 7,1
- Suspended solids: <2,5 ppm with particle size
  <250 microns

The specification for demineralised water is to be agreed by the Owner.

7.1.5 Where chilled water is used to provide a controlled environment for equipment and machinery intended for Mobility and/or Ship Type systems which require this controlled environment to function, an alternative means is to be provided to maintain the required environment in the event of a failure of the chilled water system. Failure of the chilled water system is to initiate an alarm. Duplication of the equipment requiring cooling can be provided instead of an alternative means of cooling, providing that the duplicated equipment is fed from an alternative, independent chilled water system.

7.2 Refrigeration plant

7.2.1 Two or more independent refrigeration plants are to be provided and designed to be capable of extracting the heat load duty required by *Vol 2, Pt 7, Ch 5, 7.1 General 7.1.3* when operating at the conditions stated in the System Design Description with any one plant out of action.

7.2.2 The refrigeration plants are to be located in separate compartments and zones such that the loss of one compartment or zone, or failure in equipment will not render the other refrigeration plant(s) inoperative. In NS3 category ships the requirement for pumps to be located in separate zones will not be insisted on where agreed by the Owner and included in the System Design Description.

7.2.3 The compartments containing the refrigeration plants are to be provided with refrigerant gas detectors with audible and visual alarms.

7.2.4 The design of refrigeration systems is to be such that it permits maintenance and repair without unavoidable loss of refrigerant to the atmosphere. To minimise release of ozone-depleting substances to the atmosphere, refrigerant recovery units are to be provided for evacuation of a system prior to maintenance.

7.2.5 Refrigeration systems are to be provided with relief devices, but it is important to avoid circumstances that would bring about an inadvertent discharge of refrigerant to the atmosphere. The system is to be so designed that pressure due to fire conditions will be safely relieved. Where discharge of refrigerant gas to atmosphere is unavoidable, arrangements are to be made to prevent discharge into ventilation systems.

7.2.6 A pressure relief valve and/or bursting disc is to be fitted between each positive displacement compressor and its gas delivery stop valve, the discharge being led to the suction side of the compressor. The flow capacity of the valve or disc is to exceed the full load compressor capacity on the particular refrigerant at the maximum potential suction pressure. For these internal relief valves, a servo-operated valve will be accepted. Where the motive power for the compressor does not exceed 10 kW, the pressure relief valve and/or bursting disc may be omitted.

7.2.7 Each pressure vessel which may contain liquid refrigerant and which is capable of being isolated by means of a stop or automatic control or check valve is to be protected at all times by one of two pressure relief valves or one of two bursting discs, or one bursting disc or a pressure relief valve controlled by a changeover device. Pressure vessels that are connected by pipework without valves, so that they cannot be isolated from each other, may be regarded as a single pressure vessel for this purpose, provided that the interconnecting pipework does not prevent effective venting of any pressure vessel.

7.2.8 Omission of one of the specified relief devices and changeover device, as required by *Vol 2, Pt 7, Ch 5, 7.2 Refrigeration plant 7.2.7*, will be accepted where:

(a) vessels are of less than 300 litres internal gross volume;

or

(a) vessels discharge into the low pressure side by means of a relief valve.

7.2.9 Sections of systems and components that could become full of liquid between closed valves are to be provided with pressure relief devices relieving to a suitable point in the refrigerant circuit.

7.2.10 Where hermetically sealed compressor units or semi-hermetic compressors with the electric motor cooled by the circulating refrigerant are installed, the following arrangements are to be made:

(a) Each refrigeration system containing hermetically sealed compressor units or semi-hermetic compressors is to be independent of other refrigeration systems.
(b) All hermetic motor-compressors are to be fitted with a thermal cut-out device that protects the motor against overheating.
(c) Each refrigerant circuit is to be designed such that debris or contaminants from a motor failure, typically burn out of insulation, is contained and not distributed around the system.

7.3 Water system

7.3.1 Two or more chilled water pumps are to be provided and be of sufficient capacity to circulate chilled water at the flow rate and conditions stated in the System Design Description with any one pump out of action.

7.3.2 The chilled water pumps are to be located in separate compartments and zones such that loss of one compartment or zone or failure in equipment will not render the chilled water system inoperative.

NOTE:

This does not preclude locating the chilled water pumps in the same compartment as the refrigeration plants mentioned in *Vol 2, Pt 7, Ch 5, 7.2 Refrigeration plant*. Plants and their associated chilled water pumps are to be arranged such that the pumps can be cross-connected to other plants in the event of plant or pump failure. In NS3 category ships the requirement for pumps to be located in separate zones will not be insisted on where agreed by the Owner and included in the System Design Description.

7.3.3 The chilled water distribution system is to be of the constant flow type with a pneumatically pressurised expansion tank. Expansion tanks are to have a membrane fitted at the air/water interface to prevent ingress of air into the chilled water system.

7.3.4 Each user of chilled water is to be provided with means of isolation such that the distribution system can operate at the designed constant flow rate when the user is isolated.

7.3.5 The arrangement of chilled water distribution pipes and isolation valves is to ensure continuous availability of supply in the event of the loss of any one compartment or zone.

7.3.6 Air vent and drain valves with adequate bleed off points for filling and in-service operational requirements are to be provided throughout the system at all high and low points.

7.3.7 Provision is to be made for filling and topping up the chilled water system. A means is also to be provided for connecting the system to a dry main for shore connection above the waterline. The shore connection is to be sized sufficient to enable supply of cooling water for the ship's requirement as declared in the System Design Description required by *Vol 2, Pt 7, Ch 5, 1.3 Documentation required for design review 1.3.2*.

7.3.8 Provision is to be made to connect the chilled water distribution system to an alternative source of water supply for use in emergency/action damage conditions.

7.3.9 Sea-water systems for refrigeration condensers are to be capable of being supplied from not less than two independent sources located in separate compartments and zones such that the loss of one compartment or zone, or failure in equipment will not render loss of all sea-water sources. In NS3 category ships the requirement for refrigeration condensers to be located in separate zones will not be insisted on where agreed by the Owner and included in the System Design Description.

7.3.10 The capacity of each source of sea-water required by *Vol 2, Pt 7, Ch 5, 7.3 Water system 7.3.9* is to be sufficient for the conditions stated in the System Design Description with any one source out of action.

■ *Section 8* **High pressure compressed air systems**

8.1 General

8.1.1 The requirements of this Section are additional to those contained in *Vol 2, Pt 7, Ch 5, 2 Construction and installation* of this Chapter.

8.1.2 High pressure (HP) compressed air systems are to produce and distribute compressed air throughout the ship to supply all systems and equipment where the air pressure requirement exceeds 7 bar. The systems are to include air compressors, oil/water separators, filter/dryers, distribution lines and air receivers. For the purpose of maintenance and safety regulatory requirements, HP air systems may be defined as those where the air pressure requirements exceed 25–40 bar and this is to be defined in the System Design Description required by *Vol 2, Pt 7, Ch 5, 1.3 Documentation required for design review 1.3.2*.

8.1.3 The requirements for HP compressed air systems include the storage and distribution of compressed air with air pressures above 7 bar and are to be in accordance with the System Design Description required by *Vol 2, Pt 7, Ch 5, 1.3 Documentation required for design review 1.3.2*. Additional compressed air systems may be installed for specific purposes such as for diesel engine starting (typically 25–30 bar systems) which are also to comply with the requirements of this Section and *Vol 2, Pt 7, Ch 3, 12 Air compressors and air starting arrangements* as applicable.

8.1.4 The design of HP compressed air systems is to be capable of providing continuous flow for all demands of equipment and system consumers, recognising continuous and intermittent users. This includes any portable equipment that may be part of the ship's equipment.

8.1.5 The compressed air system users' quality (dryness, purity, etc.) requirements of compressed air are to be recognised in the selection of compressors, equipment, filters and dryers to be included in the system(s).

8.1.6 Arrangements for emergency depressurisation of HP compressed air to safe positions on open deck are to be provided. The controls for emergency depressurisation are to be located in readily accessible positions outside the space containing the HP air receivers.

8.2 Compressors

8.2.1 Two or more HP air compressors are to be provided of sufficient capacity to supply the total design demand of the system under defined requirements stated in the System Design Description required by *Vol 2, Pt 7, Ch 5, 1.3 Documentation required for design review 1.3.2* with any one compressor out of action.

8.2.2 The compressors are to be located in separate compartments and zones such that the loss of one compartment or zone, or failure in equipment will not render the other compressor(s) inoperative.

8.2.3 Each compressor is to be fitted with a safety valve so proportioned and adjusted that the accumulation of pressure with the outlet valve closed will not exceed 10 per cent of the maximum working pressure of the compressor. The casings of the cooling water spaces are to be fitted with a safety valve or bursting disc so that ample relief will be provided in the event of the bursting of an air cooler tube.

8.2.4 Each compressor is to be provided with an alarm for failure of the lubricating oil supply that will initiate an automatic shutdown.

8.2.5 Adequate air supply arrangements via a steel trunk are to be provided to the compartment where the compressor is located and where a vessel is provided with an CBRN citadel, arrangements are to ensure that there is adequate air supply to the compressor in closedown. Care is to be taken to ensure that the compressor air inlets will be located in an atmosphere reasonably free from oil vapour..

8.2.6 Provision is to be made for intercepting and draining oil and water in the air discharge for which purpose a separator or filter is to be fitted in the discharge pipe from each compressor.

8.2.7 Drain valves for removing accumulations of oil and water are to be fitted on compressors and their associated coolers, separators and filters.

8.3 Air receivers

8.3.1 The HP air system and associated air receivers are to be configured to provide sufficient capacity to supply HP compressed air to users when any section of the distribution line is isolated due to failure or damage.

8.3.2 The configuration of the HP air system and associated air receivers for each essential user of HP compressed air is to be arranged to provide without replenishment, sufficient air to operate systems and equipment at an agreed capability level for an agreed period of time. In general, at least two air receivers of approximately equal capacity are to be provided for each essential user or group of users.

8.3.3 All air receivers are to be provided with mounting and fittings required by *Vol 2, Pt 8, Ch 2, 9 Mountings and fittings*.

8.3.4 Stop valves on air receivers are to permit slow opening to avoid sudden pressure rises in the piping system.

8.3.5 Air receivers used for pressurising magazine water spray systems are to be capable of being isolated from the HP compressed air distribution lines to prevent automatic replenishment of the receiver after use.

8.4 Distribution system

8.4.1 The arrangement of HP compressed air pipes and isolation valves is to ensure continuous availability of supply in the event of the loss of any one compartment or zone. Isolating valves are to be fitted in each branch from the main distribution system to permit isolation of any damaged branches.

8.4.2 Drain pots with drain valves are to be provided throughout the distribution system at all low points.

8.4.3 Reducing valves/stations for users of reduced pressure air are to be provided throughout the ship. Pipelines that are situated on the low pressure side of reducing valves/stations, and that are not designed to withstand the full pressure of the source supply, are to be provided with pressure gauges and with relief valves having sufficient capacity to protect the piping against excessive pressure. Inline filters are to be fitted at each reducing valve/station on the reduced pressure side.

8.4.4 A means is to be provided for connecting the HP compressed air system to a shore connection.

Section 9
Low pressure compressed air systems

9.1 General

9.1.1 The requirements of this Section are additional to those contained in *Vol 2, Pt 7, Ch 5, 2 Construction and installation* of this Chapter.

9.1.2 Low pressure (LP) compressed air systems are to produce and distribute oil and moisture free cool compressed air throughout the ship to supply all systems and equipment where the air pressure requirements are 7 bar and below. The systems are to include air compressors, oil/water separators, filter/dryers, distribution lines and air receivers. For the purpose of maintenance and safety regulatory requirements, LP air systems may be defined as those where the air pressure requirements are 25–40 bar and below and this is to be defined in the System Design Description required by *Vol 2, Pt 7, Ch 5, 1.3 Documentation required for design review 1.3.2*.

9.1.3 The design of LP compressed air systems is to be capable of providing continuous flow for all demands of equipment and system consumers recognising continuous and intermittent users. This includes any portable equipment that may be part of the ship's equipment. Compressed air systems used for specific purposes such as for diesel engine or gas turbine starting are also to comply with the requirements of this Section and *Vol 2, Pt 7, Ch 3, 12 Air compressors and air starting arrangements* and *Vol 2, Pt 2, Ch 2, 6 Materials* as applicable.

9.1.4 The quality (dryness, purity, etc) requirements of compressed air is to be recognised in the selection of compressors, equipment, filters and dryers to be included in the system(s).

9.1.5 Configuration arrangements of LP compressed air systems may consist of:

(a) Dedicated LP air compressors and LP air receivers with a distribution system for LP users; or
(b) Dedicated LP air compressors feeding directly into a distribution system for LP air users; or
(c) Supply from the HP air system to dedicated air pressure reducing valves/stations and air receivers feeding into a distribution system for LP users.

Where the arrangements are configured as described in *Vol 2, Pt 7, Ch 5, 9.1 General 9.1.5* and *Vol 2, Pt 7, Ch 5, 9.1 General 9.1.5*, arrangements are to be made for connections to the LP air system via reducing valves/stations from the HP compressed air system.

9.2 Compressors and reducing valves/stations

9.2.1 Where LP air is not derived from the HP air system, two or more LP air compressors are to be provided of sufficient capacity to supply the total design demand of the system with any one compressor out of action.

9.2.2 With the exception of the need to trunk in an air supply for CBRN design in *Vol 2, Pt 7, Ch 5, 8.2 Compressors 8.2.5*, the requirements of *Vol 2, Pt 7, Ch 5, 8.2 Compressors 8.2.2* to *Vol 2, Pt 7, Ch 5, 8.2 Compressors 8.2.7* are also to be complied with for LP air compressors.

9.2.3 Where the design of the LP compressed air system requires the use of dedicated LP air compressors feeding directly into a distribution system of LP air users, the compressors are to be capable of continuous running with arrangements for ensuring that compressor output matches demand.

9.2.4 Where LP air is derived only from a HP compressed air system, two or more reducing valves/stations are to be provided of sufficient capacity to supply the total demand of the LP air system with any one reducing valve/station out of action.

9.3 Air receivers

9.3.1 The LP air system and associated air receivers are to be configured to provide sufficient capacity to supply LP compressed air to users when the distribution line is isolated due to failure or damage.

9.3.2 The configuration of the LP air system and associated air receivers for each essential user of LP compressed air is to be arranged to provide, without replenishment, sufficient air to operate systems and equipment at an agreed capability level for an agreed period of time. In general, at least two air receivers of approximately equal capacity are to be provided for each essential user or group of users.

9.3.3 All air receivers are to be provided with mounting and fittings required by *Vol 2, Pt 8, Ch 2, 9 Mountings and fittings*.

9.3.4 Stop valves on air receivers are to permit slow opening to avoid sudden pressure rises in the piping system.

9.4 Distribution system

9.4.1 The arrangement of LP compressed air pipes and isolation valves is to ensure continuous availability of supply in the event of the loss of any one compartment or zone. Isolating valves are to be fitted in each branch from the distribution system(s) to permit isolation of any damaged branches.

9.4.2 Drain pots with drain valves are to be provided throughout the distribution system at all low points.

9.4.3 Reducing valves/stations for users of reduced pressure air are to be provided throughout the ship. Pipelines that are situated on the low pressure side of reducing valves/stations, and that are not designed to withstand the full pressure of the source supply, are to be provided with pressure gauges and with relief valves having sufficient capacity to protect the piping against excessive pressure. In-line filters are to be fitted at each reducing valve/station on the reduced pressure side.

9.4.4 A means is to be provided for connecting the LP compressed air system to a shore connection.

■ *Section 10*
High pressure sea-water systems

10.1 General

10.1.1 The requirements in this Section are additional to those contained in *Vol 2, Pt 7, Ch 5, 2 Construction and installation* of this Chapter.

10.1.2 High pressure sea-water (HPSW) systems are to continuously supply and distribute sea-water at a pressure of generally not less than 7 bar throughout the ship to provide water for fire-fighting, magazine spraying, pre-wetting, bilge and dewatering eductors and emergency cooling. *See Vol 2, Pt 7, Ch 5, 10.2 Pump units 10.2.6* for water pressure requirements.

10.1.3 The pumping and delivery capacities and pressures from the HPSW are to be sufficient to support damage control and fire-fighting policy, procedures and techniques, including pre-wet requirements that are to be declared in the System Design Description required by *Vol 2, Pt 7, Ch 5, 1.3 Documentation required for design review 1.3.2*.

10.1.4 Ship-side valves and fittings are to comply with the requirements of *Vol 2, Pt 7, Ch 2, 2.5 Ship-side valves and fittings (other than those on scuppers and sanitary discharges)* as applicable.

10.2 Pump units

10.2.1 Three or more HPSW pumps are to be provided of sufficient capacity to supply the total pumping capacity defined in *Vol 2, Pt 7, Ch 5, 10.2 Pump units 10.2.3* with any one pump out of action. At least one of the pumps is to be capable of supplying HPSW in a dead ship condition.

10.2.2 The pumps are to be located in separate compartments and zones such that the loss of one compartment or zone or failure in equipment will not render the other pumps inoperative.

10.2.3 The total pumping capacity of the HPSW pumps with one pump out of action shall provide for the greatest of the following:

(a) The amount required for pre-wetting.
(b) The amount required for a fire in the largest machinery space using the largest fixed spray system plus 40 m^3/hr boundary cooling from hoses.
(c) The amount required for a major fire outside the machinery spaces using 100 m^3/hr boundary cooling for each fire. The minimum number of fires to be considered is as follows:
    (i) Displacement at design draught of under 4,000 tonnes – one fire
    (ii) Between 4,000 and 10,000 tonnes – two fires
    (iii) Between 10,000 and 20,000 tonnes – three fires
    (iv) Over 20,000 tonnes – four fires

Reference is also to be made to the System Design Description required by *Vol 2, Pt 7, Ch 5, 1.3 Documentation required for design review 1.3.2* where the number of fires to be considered may also reference amongst other items, the type of ship, number of personnel on board and number of fire zones.

(d) The largest single magazine or ammunition transfer space spray requirement plus 40 m^3/hr boundary cooling.

(e) The hangar spray requirement in the largest area contained by a fire curtain.

(f) A flight deck fire requiring one third of the total foam branch pipes fitted in multi-aircraft landing (multi-spot) ships or two foam branch pipes in single aircraft landing (single spot) ships.

If the factor determining the total pumping capacity is (b), then any pumps located in the space are to be added to the overall number of pumps required.

10.2.4 The capacity of each pump is to be not less than that required to supply water for the eductor capacities referred to in *Vol 2, Pt 7, Ch 2, 6.3 Capacity of pumps and educators*.

10.2.5 The sea suctions to HPSW pumps are to be provided with an air elimination arrangement to ensure that the running and standby pumps do not become air-locked.

10.2.6 HPSW pumps are to be arranged to operate continuously with automatic and switched means of starting of standby pumps on sea-water demand. Automatic starting of standby pumps may be achieved by sensing when the system pressure falls below a pre-set level. The continuous and minimum supply pressures in the HPSW distribution system are to be in accordance with the System Design Description required by *Vol 2, Pt 7, Ch 5, 1.3 Documentation required for design review 1.3.2*.

10.2.7 HPSW pumps are to be provided with high temperature alarms for components that may become overheated when the pump is running in low or no flow demand conditions.

10.2.8 Where HPSW pumps can develop a pressure greater than the design pressure of the system, they are to be provided with pressure relief/control devices on the pump discharge to effectively limit the pump discharge pressure to the design pressure of the system.

10.2.9 Strainers capable of being cleaned without interruption of water flow to the pumps are to be provided in the suction pipes.

10.3 Distribution system

10.3.1 The arrangement of the HPSW system is to ensure continuous availability of supply in the event of the loss of any compartment or zone. Isolating valves are to be fitted in each branch from the main distribution system to permit isolation of any damaged branches.

10.3.2 HPSW should be supplied throughout the ship by means of a ring main system. In multi-spot ships fitted with a between deck hangar, a second ring main should be provided. These ring mains are to be cross-connected but may share the same pumps. Alternative arrangements to a ring main system will be considered where a vulnerability assessment has demonstrated that continuous availability of HPSW can be ensured whilst satisfying the system arrangement requirements of this Chapter.

10.3.3 Ring mains are to extend over the middle two thirds of the length of the ship, one half to port and the other to the starboard side. Each ring main is to be cross-connected across the ship in separate fire zones recognising any vulnerability requirements stated by the Owner. The main is to be extended forward and aft of the ring main by a single line of piping at the centre.

10.3.4 The HPSW system is to be capable of being isolated into separate sections by local and remote controlled valves at the fire zone boundaries. In addition, isolating valves are to be fitted at the following locations:

(a) At the riser from the pump to the ring main.

(b) In the ring main each side of the pump riser junction.

(c) At each cross-over connection junction to the ring main.

(d) Where the ring main penetrates a watertight bulkhead.

(e) In the ring main each side of the branch to the magazine spray system.

10.3.5 Where the HPSW system is to be used for firefighting purposes, the supplies are to be led through vertical distribution lines directly from the horizontal ring main to the upper deck levels.

10.3.6 Shore and ship to ship connections to the HPSW ring main are to be provided port and starboard on the weatherdeck – one pair forward, the other aft, i.e. a total of four connections. For **NS3** category ships with a breadth not exceeding 10 m, a single connection forward and a single connection aft will be acceptable.

Section 11
Hydraulic power actuating systems

11.1 General

11.1.1 The requirements of this Section are additional to those contained in *Vol 2, Pt 7, Ch 5, 2 Construction and installation* of this Chapter. The requirements do not apply to steering systems that are covered in *Vol 2, Pt 6, Ch 1 Steering Gear*.

11.1.2 The arrangements for storage, distribution and utilisation of hydraulic and flammable oils employed under pressure in power transmission systems, control and actuating systems, heating systems and hydraulic media in systems which are part of Mobility systems or Ship Type systems, are to comply with the requirements of this Section.

11.1.3 Hydraulic power actuating systems are to deliver hydraulic fluid under pressure for actuation of hydraulically driven machinery and for operation of remote controlled equipment.

11.1.4 Hydraulic fluids are to be suitable for the intended purpose under all operating service conditions and conform to the Owner's safety policy where applicable.

11.1.5 Materials used for all parts of hydraulic seals are to be compatible with working fluid at the appropriate working temperature and pressure.

11.1.6 Hydraulic power actuating systems for hydraulically driven machinery and for the operation of remotely controlled equipment are to be independent of each other.

11.2 Hydraulic fluid storage

11.2.1 Tanks and reservoirs for service and the storage of hydraulic fluids are to be made of steel and suitable for the maximum head of fluid to which the tanks may be subjected. In general, tanks are to have a minimum plate thickness of 5 mm, but in the case of very small tanks, the minimum thickness may be 3 mm.

11.2.2 The storage capacity for hydraulic fluid(s) is to be sufficient to recharge the largest system on board plus normal usage during a typical mission. Storage capacity is to be sufficient for each type of hydraulic fluid used on the ship. Storage capability sufficient to handle the full capacity of the largest hydraulic system on board is also to be provided for dirty hydraulic fluids.

11.2.3 Tanks and reservoirs are to be provided with two connections at diagonally opposite corners, one top and one bottom to permit the contents to be circulated through portable flushing equipment.

11.2.4 The capacity of hydraulic fluid reservoirs at normal working level is to ensure a residence time for the fluid of not less than three minutes.

11.2.5 A vertical baffle plate is to be fitted dividing each reservoir into two compartments interconnected at the top of the baffle. Return fluid, drains, etc. are to be made to one side of the baffle whilst pump suctions are to be taken from the other side.

11.2.6 All tanks and reservoirs are to be provided with approved means of hydraulic fluid level indication.

11.2.7 All tanks and reservoirs are to be provided with approved means of sampling the contents and a means of access for cleaning.

11.3 Pump units

11.3.1 Two or more hydraulic pumps are to be provided for each power actuating system. The pumps are to be of sufficient capacity to supply the system under defined operational requirements stated in the System Design Description required by *Vol 2, Pt 7, Ch 5, 1.3 Documentation required for design review 1.3.2* with any one pump out of action.

11.3.2 All hydraulic pumps are to be provided with relief valves. Each relief valve is to be in close circuit, i.e. arranged to discharge back to the suction side of the pump and effectively to limit the pump discharge pressure to the design pressure of the system.

11.3.3 The power supply to all independently driven pumps used for pumping flammable fluids is to be capable of being stopped from a position outside the space. It shall be possible to activate the stop from this position in the event of a fire occurring in the space containing the pumps, in addition to any stop facilities provided in the space.

11.3.4 Where pump units are provided with accumulators, a shut-off valve is to be provided between the pressure line and the accumulator with a bleed valve fitted between the shut-off valve and the accumulator.

11.3.5 Where accumulators are provided with gas pressurisation, isolating valves are to be fitted in the gas lines at each accumulator. A relief valve is to be fitted in the gas supply line to limit prevent the accumulator being pressurised above its maximum working pressure.

11.4 Supply systems and arrangements

11.4.1 Supply systems to hydraulic power actuating systems are to be as short as practicable.

11.4.2 Where hydraulic pipes penetrate watertight or fire zone bulkheads, isolating valves are to be provided.

11.4.3 The use of flexible hoses is to be restricted to positions where it is necessary to accommodate relative movement between items of equipment and fixed pipe-work.

11.4.4 Where emergency fire valves are hydraulically operated, accumulators are to be provided in the common supply lines to facilitate rapid operation of the valve actuators in the event of fire.

11.4.5 Provision is to be made for emergency hand pump or hand wheel operation of hydraulic systems.

11.4.6 Where a hydraulic securing is applied, the system is to be capable of being mechanically locked in the closed position so that, in the event of hydraulic system failure, the securing arrangements will remain locked.

11.4.7 Where pilot operated non-return valves are fitted to hydraulic cylinders for locking purposes, the valves are to be connected directly to the actuating cylinder(s) without intermediate pipes or hoses.

11.4.8 Hydraulic circuits for securing and locking of bow, inner, stern or shell doors are to be arranged such that they are physically unable to be affected by operation of other hydraulic circuits when securing and locking devices are in the closed position. For requirements relating to hydraulic steering gear arrangements, *see Vol 2, Pt 6, Ch 1, 5.3 Components*.

11.4.9 Suitable oil collecting arrangements for leaks shall be fitted below hydraulic valves and cylinders.

11.5 Cooling arrangements

11.5.1 Cooling arrangements for hydraulic fluids are to be provided where the operating temperature of the fluid may exceed the maximum design temperature limitations of the fluid or equipment in the system as defined in the System Design Description required by *Vol 2, Pt 7, Ch 5, 1.3 Documentation required for design review 1.3.2*.

11.5.2 Where the provision of cooling arrangements is necessary to maintain hydraulic fluid temperatures, not less than two means of cooling are to be provided and configured such as to provide cooling with one means out of action.

11.6 Relief valves on pumps

11.6.1 All pumps which are capable of developing a pressure exceeding the design pressure of the system are to be provided with relief valves. Each relief valve is to be in closed circuit, i.e. arranged to discharge back to the suction side of the pump and effectively to limit the pump discharge pressure to the design pressure of the system.

11.7 Pipes conveying oil

11.7.1 Piping systems for flammable hydraulic fluids are to be installed to avoid fluid spray or leakage onto hot surfaces, into machinery air intakes, or other sources of ignition such as electrical equipment. Pipe joints are to be kept to a minimum, and where provided are to be of a type acceptable to LR. Pipes are to be led in well lit and readily visible positions.

11.7.2 Pipes conveying hydraulic oil under pressure are to be of seamless steel or other approved material having flanged or welded joints, and are to be placed in sight above the platform in well lit and readily accessible parts of the machinery spaces. The number of flanged joints is to be kept to a minimum.

11.7.3 For requirements relating to flexible hoses, *see Vol 2, Pt 7, Ch 1, 13 Flexible hoses*.

11.8 Filling arrangements

11.8.1 Filling stations are to be isolated from other spaces and are to be efficiently drained and ventilated.

11.9 Separate oil tanks

11.9.1 On completion, the tanks are to be tested by a head of water equal to the maximum to which the tanks may be subjected.

11.10 Precautions against fire

11.10.1 Hydraulic oil tanks and filters are not to be situated immediately above boilers or other highly heated surfaces.

11.10.2 Hydraulic oil pipes are not to be installed above or near high-temperature equipment. Hydraulic oil pipes should also be installed and screened, or otherwise suitably protected, to avoid oil spray or oil leakages onto hot surfaces, into machinery air intakes, or other sources of ignition such as electrical equipment. Pipe joints are to be kept to a minimum and where provided are to be of a type acceptable to LR. Pipes are to be led in well lit and readily visible positions.

11.10.3 Pumps, filters and heaters are to be located to avoid hydraulic oil spray or leakage onto hot surfaces or other sources of ignition or onto rotating machinery parts. Where necessary, shielding is to be provided and the arrangements are to allow easy access for routine maintenance. The design of filter and strainer arrangements is to be such as to avoid the possibility of them being opened inadvertently when under pressure. This may be achieved either by mechanically preventing the pressurised filter from being opened or by providing pressure gauges which clearly indicate which filter is under pressure. In either case, suitable means for pressure release are to be provided, with drain pipes led to a safe location.

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter are applicable to fusion welded pressure vessels and their mountings and fittings, for the following uses:

(a) Production or storage of steam.
(b) Heating of pressurised hot water above 120°C.
(c) Heating of pressurised thermal liquid.

The formulae in this Chapter may be used for determining the thickness of seamless pressure vessels using a joint factor of 1,0. Seamless pressure vessels are to be manufactured and tested in accordance with the requirements of *Ch 5 Steel Forgings* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2015* (hereinafter referred to as the Rules for Materials.

1.1.2 The scantlings of coil type heaters with pumped circulation, which are fired or heated by exhaust gas, are to comply with the appropriate requirements of this Chapter.

1.2 Definition of symbols

1.2.1 The symbols used in the various formulae in *Vol 2, Pt 8, Ch 1, 2 Cylindrical shells and drums subject to internal pressure*, unless otherwise stated, are defined as follows and are applicable to the specific part of the pressure vessel under consideration:

d = diameter of hole or opening, in mm

p = design pressure, *see Vol 2, Pt 8, Ch 1, 1.3 Design pressure*, in bar

r_i = inside knuckle radius, in mm

r_o = outside knuckle radius, in mm

s = pitch, in mm

t = minimum thickness, in mm

D_i = inside diameter, in mm

D_o = outside diameter, in mm

J = joint factor applicable to welded seams, *see Vol 2, Pt 8, Ch 1, 1.9 Joint factors*, or ligament efficiency between tube holes (expressed as a fraction, *see Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes*)

R_i = inside radius, in mm

R_o = outside radius, in mm

T = design temperature, in ºC

σ = allowable stress, *see Vol 2, Pt 8, Ch 1, 1.8 Allowable stress*, in N/mm^2.

1.2.2 Where reference is made to calculated or actual plate thickness for the derivation of other values, these thicknesses are to be minus the standard Rule corrosion allowance of 0,75 mm, if not so stated.

1.3 Design pressure

1.3.1 The design pressure is the maximum permissible working pressure and is to be not less than the highest set pressure of any safety valve.

1.3.2 The calculations made to determine the scantlings of the pressure parts are to be based on the design pressure, adjusted where necessary to take account of pressure variations corresponding to the most severe operational conditions.

1.3.3 It is desirable that there should be a margin between the normal pressure at which the boiler or pressure vessel operates and the lowest pressure at which any safety valve is set to lift, to prevent unnecessary lifting of the safety valve.

1.4 Metal temperature

1.4.1 The metal temperature, T, used to evaluate the allowable stress, σ, is to be taken as the actual mean wall metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when plans of the pressure parts are submitted for consideration.

1.4.2 The following values are to be regarded as the minimum:

(a) For fired steam boilers, T is to be taken as not less than 250ºC.

(b) For steam heated generators, secondary drums of double evaporation boilers, steam receivers and pressure parts of fired pressure vessels, not heated by hot gases and adequately protected by insulation, T is to be taken as the maximum temperature of the internal fluid.

(c) For pressure parts heated by hot gases, T, is to be taken as not less than 25ºC in excess of the maximum temperature of the internal fluid.

(d) For boiler, superheater, reheater and economiser tubes, *T* is to be taken as indicated in *Vol 2, Pt 8, Ch 1, 7.1 Minimum thickness 7.1.2*

(e) For combustion chambers of the type used in horizontal wet-back boilers, *T*, is to be taken as not less than 50ºC in excess of the maximum temperature of the internal fluid.

(f) For furnaces, fireboxes, rear tube plates of dry-back boilers and pressure parts subject to similar rates of heat transfer, *T*, is to be taken as not less than 90ºC in excess of the maximum temperature of the internal fluid.

1.4.3 In general, any parts of boiler drums or headers not protected by tubes, and exposed to radiation from the fire or to the impact of hot gases, are to be protected by a shield of good refractory material or by other approved means.

1.4.4 Drums and headers of thickness greater than 35 mm are not to be exposed to combustion gases having an anticipated temperature in excess of 650ºC unless they are efficiently cooled by closely arranged tubes.

1.5 Classification of fusion welded pressure vessels

1.5.1 For Rule purposes, pressure vessels with fusion welded seams are graded as Class 1 if they comply with the following conditions:

(a) For pressure parts of fired steam boilers, fired thermal liquid heaters and exhaust gas heated shell type steam boilers where the design pressure exceeds 3,4 bar.

(b) For pressure parts of steam heated steam generators and separate steam receivers where the design pressure exceeds 11,3 bar, or where the pressure, in bar, multiplied by the internal diameter of the shell, in mm, exceeds 14 420.

1.5.2 For Rule purposes, pressure vessels with fusion welded seams, used for the production or storage of steam, the heating of pressurised hot water above 120ºC or the heating of pressurised thermal liquid not included in Class 1 are graded as Class 2/1 and 2/2.

1.5.3 Pressure vessels which are constructed in accordance with Class 2/1 or Class 2/2 standards (as indicated above) will, if manufactured in accordance with requirements of a superior class, be approved with the scantlings appropriate to that class.

1.5.4 Pressure vessels which have only circumferential fusion welded seams, will be considered as seamless with no class being assigned. Preliminary weld procedure tests and non-destructive examination for the circumferential seam welds should be carried out for the equivalent class as determined by *Vol 2, Pt 8, Ch 1, 1.5 Classification of fusion welded pressure vessels 1.5.1* and *Vol 2, Pt 8, Ch 1, 1.5 Classification of fusion welded pressure vessels 1.5.2*.

1.5.5 In special circumstances relating to service conditions, materials, operating temperature, the carriage of dangerous gases and liquids, etc. it may be required that certain pressure vessels be manufactured in accordance with the requirements of a superior class.

1.5.6 Details of heat treatment, non-destructive examination and routine tests (where required) are given in *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

1.5.7 Hydraulic testing is required for pressure vessels of Class 1, 2/1 and 2/2.

1.6 Plans

1.6.1 Plans of boilers, superheaters and economisers are to be submitted in triplicate for consideration. When plans of water tube boilers are submitted for approval, particulars of the safety valves and their disposition on boilers and superheaters, together with the estimated pressure drop through the superheaters, are to be stated. The pressures proposed for the settings of boiler and superheater safety valves are to be indicated on the boiler plan.

1.6.2 Plans, in triplicate, showing full constructional features of fusion welded pressure vessels and dimensional details of the weld preparation for longitudinal and circumferential seams and attachments, together with particulars of the welding consumables and of the mechanical properties of the materials, are to be submitted before construction is commenced.

1.6.3 Plans, in triplicate, showing details of the air flow through the combustion chamber, boiler furnace and boiler uptake spaces, including measures taken to assure effective purging in all of the spaces, are to be submitted for consideration, *see also Vol 2, Pt 8, Ch 1, 18.2 Automatic and remote controls* and *Vol 2, Pt 7, Ch 3, 9.3 Thermal fluid heaters*.

1.6.4 Plans, in triplicate, showing all areas of refractory in the combustion chamber and boiler furnace spaces, are to be submitted for consideration, *see Vol 2, Pt 8, Ch 1, 1.12 Furnace explosion prevention 1.12.1*.

1.6.5 Calculations, in triplicate, that show a minimum of 4 air changes of the combustion chamber, boiler furnace and boiler uptake spaces will be achieved during automatic purging operations, with details of the forced draft fans and arrangements of air

flow from fan intake to flue outlet, are to be submitted for consideration, *see Vol 2, Pt 8, Ch 1, 1.12 Furnace explosion prevention 1.12.1*.

1.6.6 Calculations, in triplicate, that show that the ventilation of machinery spaces containing boilers is adequate for the air consumers within the space and unrestricted air supply to the items of plant is ensured under operating conditions.

1.7 Materials

1.7.1 Materials used in the construction are to be manufactured and tested in accordance with the requirements of the*Rules for the Manufacture, Testing and Certification of Materials, July 2015*.

1.7.2 The specified minimum tensile strength of carbon and carbon-manganese steel plates, pipes, forgings and castings is to be within the following general limits:

(a) For seamless, Class 1, Class 2/1 and Class 2/2 fusion welded pressure vessels:

340 to 520 N/mm^2.

(b) For boiler furnaces, combustion chambers and flanged plates:

400 to 520 N/mm^2.

1.7.3 The specified minimum tensile strength of low alloy steel plates, pipes, forgings and castings is to be within the general limits of 400 to 500 N/mm^2, and pressure vessels made in these steels are to be either seamless or Class 1 fusion welded.

1.7.4 The specified minimum tensile strength of boiler and superheater tubes is to be within the following general limits:

(a) Carbon and carbon-manganese steels:

320 to 460 N/mm^2.

(b) Low alloy steels:

400 to 500 N/mm^2.

1.7.5 Where it is proposed to use materials other than those specified in the *Rules for the Manufacture, Testing and Certification of Materials, July 2015*, details of the chemical compositions, heat treatment and mechanical properties are to be submitted for approval. In such cases the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement by Lloyd's Register (hereinafter referred to as 'LR').

1.7.6 Where a fusion welded pressure vessel is to be made of alloy steel, and approval of the scantlings is required on the basis of the high temperature properties of the material, particulars of the welding consumables to be used, including typical mechanical properties and chemical composition of the deposited weld metal, are to be submitted for approval.

1.8 Allowable stress

1.8.1 The term ‘allowable stress’, σ, is the stress to be used in the formulae for the calculation of scantlings of pressure parts.

1.8.2 The allowable stress, σ, is to be the lowest of the following values:

$$\sigma = \frac{E_t}{1,5} \quad \sigma = \frac{R_{20}}{2,7} \quad \sigma = \frac{S_R}{1,5}$$

where

E_t = specified minimum lower yield stress or 0,2 per cent proof stress at temperature, T

R_{20} = specified minimum tensile strength at room temperature

S_R = average stress to produce rupture in 100 000 hours at temperature, T

T = metal temperature, *see Vol 2, Pt 8, Ch 1, 1.4 Metal temperature*

1.8.3 The allowable stress for steel castings is to be taken as 80 per cent of the value determined by the method indicated in *Vol 2, Pt 8, Ch 1, 1.8 Allowable stress 1.8.2*, using the appropriate values for cast steel.

1.8.4 Where steel castings, which have been tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2015*, are also subjected to nondestructive tests, consideration will be given to increasing the

allowable stress using a factor up to 90 per cent in lieu of the 80 per cent referred to in *Vol 2, Pt 8, Ch 1, 1.8 Allowable stress 1.8.3*. Particulars of the nondestructive test proposals are to be submitted for consideration.

1.9 Joint factors

1.9.1 The following joint factors are to be used in the equations in *Vol 2, Pt 8, Ch 1, 2 Cylindrical shells and drums subject to internal pressure*, where applicable. Fusion welded pressure parts are to be made in accordance with *Vol 2, Pt 1, Ch 4 Requirements for Fusion Welding of Pressure Vessels and Piping*

Class of pressure vessel	Joint factor
Class 1	1,0
Class 2/1	0,85
Class 2/2	0,75

1.9.2 The longitudinal and circumferential joints for all classes of pressure vessels for the purposes of this Chapter are to be butt joints. For typical acceptable methods of attaching dished ends, *see Figure 1.14.1 Typical attachments of dished ends to cylindrical shells*

1.10 Pressure parts of irregular shape

1.10.1 Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of formulae in *Vol 2, Pt 8, Ch 1, 2 Cylindrical shells and drums subject to internal pressure*, the suitability of their construction is to be determined by hydraulic proof test of a prototype or by agreed alternative method.

1.11 Adverse working conditions

1.11.1 Where working conditions are adverse, special consideration may be required to be given to increasing the scantlings derived from the formulae. In this connection, where necessary, account should also be taken of any excess of loading resulting from:

(a) impact loads, including rapidly fluctuating pressures;
(b) weight of the vessel and normal contents under operating and test conditions;
(c) superimposed loads such as other pressure vessels, operating equipment, insulation, corrosion-resistant or erosion-resistant linings and piping;
(d) reactions of supporting lugs, rings, saddles or other types of supports; or
(e) the effect of temperature gradients on maximum stress.

1.12 Furnace explosion prevention

1.12.1 The design of combustion chamber and furnace arrangements is to incorporate measures to minimise the risk of explosion as far as practicable. Measures are to be taken to prevent the accumulation of flammable gases in spaces which may not effectively be reached by purging air. Measures are to be taken to minimise heat retaining surfaces e.g. refractory which can become a source of ignition in the furnace and uptakes.

1.13 Exhaust gas economiser/boiler arrangements

1.13.1 The design of exhaust gas economisers/boilers of the plain or extended surface fin tube types is to be compatible with the installed engine design parameters. The parameters which influence the build up of soot deposits and overheating such as fuel, exhaust gas temperature and efflux velocity are to be considered in the design of the exhaust gas economiser/boiler for use with the installed engine, in order to minimise the risk of fire and breakdown during operation.

1.13.2 A System Design Description demonstrating compliance with the requirements of *Vol 2, Pt 8, Ch 1, 1.13 Exhaust gas economiser/boiler arrangements 1.13.1* or alternative means of preventing the accumulation of soot or overheating, such as the use of exhaust gas bypass ducting with automatic flap valve arrangements and/or effective soot prevention and cleaning systems, is to be submitted for approval.

■ Section 2
Cylindrical shells and drums subject to internal pressure

2.1 Minimum thickness

2.1.1 Minimum thickness, *t*, of a cylindrical shell is to be determined by the following formula:

$$t = \frac{p\,R_{\mathrm{i}}}{10\,\sigma\,J - 0,5p} + 0,75\mathrm{mm}$$

where *t*, *p*, R_{i} and σ are defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

J = efficiency of ligaments between tube holes or other openings in the shell or the joint factor of the longitudinal joints (expressed as a fraction). *See Vol 2, Pt 8, Ch 1, 1.9 Joint factors* or *Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes*, whichever applies. In the case of seamless shells clear of tube holes or other openings, *J* = 1,0.

2.1.2 The formula in *Vol 2, Pt 8, Ch 1, 2.1 Minimum thickness 2.1.1* is applicable only where the resulting thickness does not exceed half the internal radius, i.e. where R_{o} is not greater than $1,5R_{\mathrm{i}}$.

2.1.3 Irrespective of the thickness determined by the above formula, t is to be not less than:

(a) 6,0 mm for cylindrical shell plates.

(b) For tube plates, such thickness as will give a minimum parallel seat of 9,5 mm, or such greater width as may be necessary to ensure tube tightness, *see Vol 2, Pt 8, Ch 1, 14.6 Fitting of tubes in water tube boilers*

2.2 Efficiency of ligaments between tube holes

2.2.1 Where tube holes are drilled in a cylindrical shell in a line or lines parallel to its axis, the efficiency, *J*, of the ligaments is to be determined as in *Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes 2.2.2*, *Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes 2.2.3* and *Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes 2.2.4*.

2.2.2 **Regular drilling.** Where the distance between adjacent tube holes is constant, *see Figure 1.2.1 Regular drilling*,

$$J = \frac{s - d}{s}$$

where

d = the mean effective diameter of the tube holes, in mm, after allowing for any serrations, counterboring or recessing, or the compensating effect of the tube stub. *See Vol 2, Pt 8, Ch 1, 2.3 Compensating effect of tube stubs* and *Vol 2, Pt 8, Ch 1, 2.4 Unreinforced openings*.

s = pitch of tube holes, in mm.

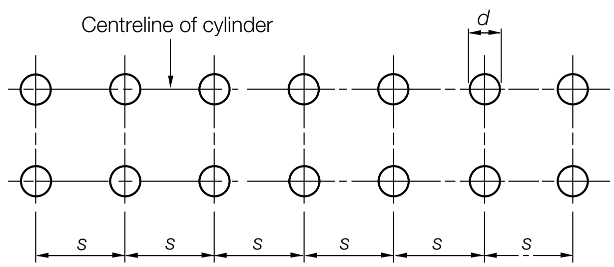


Figure 1.2.1 Regular drilling

2.2.3 **Irregular drilling**. Where the distance between centres of adjacent tube holes is not constant, *see Figure 1.2.2 Irregular drilling*

$$J = \frac{s_1 + s_2 - 2d}{s_1 + s_2}$$

where *d* is as defined in *Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes 2.2.2*

s_1 = the shorter of any two adjacent pitches, in mm

s_2 = the longer of any two adjacent pitches, in mm.

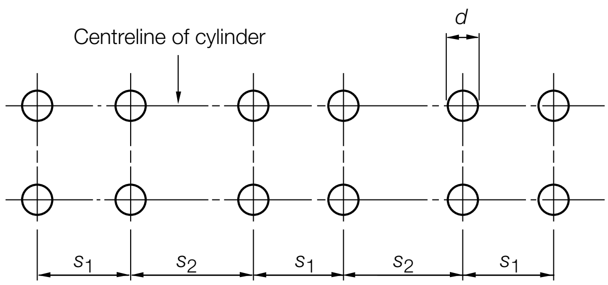


Figure 1.2.2 Irregular drilling

2.2.4 When applying the formula in *Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes 2.2.3*, the double pitch ($s_1 + s_2$) chosen is to be that which makes *J*, a minimum, and in no case is s_2 to be taken as greater than twice s_1.

2.2.5 Where the circumferential pitch between tube holes measured on the mean of the external and internal drum or header diameters is such that the circumferential ligament efficiency determined by the formula in *Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes 2.2.2* and *Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes 2.2.3* is less than one-half of the ligament efficiency on the longitudinal axis, *J* in *Vol 2, Pt 8, Ch 1, 2.1 Minimum thickness* is to be taken as twice the circumferential efficiency.

2.2.6 Where tube holes are drilled in a cylindrical shell along a diagonal line with respect to the longitudinal axis, the efficiency, *J*, of the ligaments is to be determined as in *Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes 2.2.7* to *Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes 2.2.10*.

2.2.7 For spacing of tube holes on a diagonal line as shown in *Figure 1.2.3 Spacing of holes on a diagonal line*, or in a regular saw-tooth pattern as shown in *Figure 1.2.4 Regular saw-tooth pattern of holes*, *J* is to be determined from the formula in *Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes 2.2.8*, where *a* and *b*, as shown in *Figure 1.2.3 Spacing of holes on a diagonal line* and *Figure 1.2.4 Regular saw-tooth pattern of holes*, are measured, in mm, on the median line of the plate, and *d* is as defined in *Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes 2.2.2*

2.2.8 For tube holes on a diagonal line:

$$J = \frac{2}{A + B + \sqrt{(A-B)^2 + 4C^2}}$$

where

A = $\dfrac{cos^2\,\alpha + 1}{2\left(1 - \frac{d\cos\,\alpha}{a}\right)}$

B = $0,5\left(1 - \dfrac{d\cos\,\alpha}{a}\right)\left(sin^2\,\alpha + 1\right)$

C = $\dfrac{sin\,\alpha\;cos\,\alpha}{2\left(1 - \frac{d\cos\,\alpha}{a}\right)}$

$$\cos \alpha = \frac{1}{\sqrt{1 + \frac{b^2}{a^2}}}$$

$$\sin \alpha = \frac{1}{\sqrt{1 + \frac{a^2}{b^2}}}$$

α = angle between centreline of cylinder and centreline of diagonal holes.

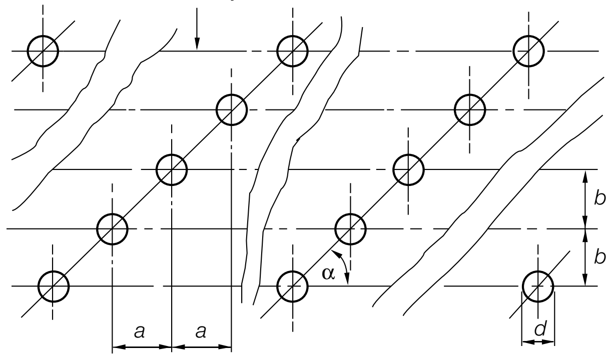


Figure 1.2.3 Spacing of holes on a diagonal line

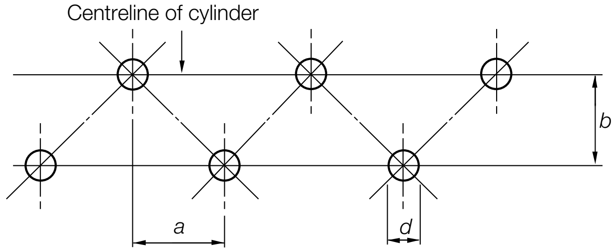


Figure 1.2.4 Regular saw-tooth pattern of holes

2.2.9 For regularly staggered spacing of tube holes as shown in *Figure 1.2.5 Regular staggering of holes*, the smallest value of the efficiency, *J*, of all ligaments (longitudinal, circumferential and diagonal) is to be used where *a* and *b* as shown in *Figure 1.2.5 Regular staggering of holes* are measured, in mm, on the median line of the plate, and *d* is as defined in *Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes 2.2.2*

2.2.10 For irregularly spaced tube holes whose centres do not lie on a straight line, the formula in *Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes 2.2.3* is to apply, except that an equivalent longitudinal width of the diagonal ligament is to be used. An equivalent longitudinal width is that width which gives, using the formula in *Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes 2.2.2*, the same efficiency as would be obtained using the formula in *Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes 2.2.8* for the diagonal ligament in question.

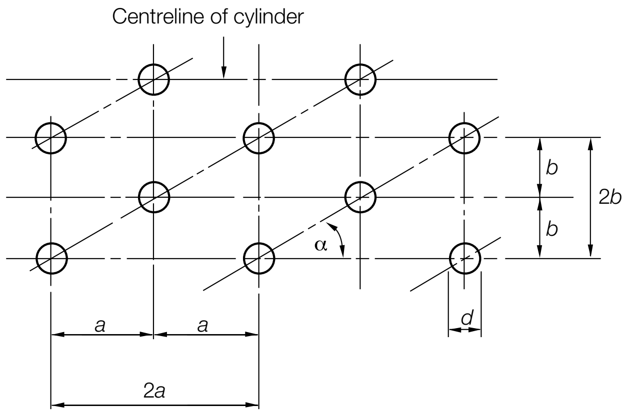


Figure 1.2.5 Regular staggering of holes

2.3 Compensating effect of tube stubs

2.3.1 Where a drum or header is drilled for tube stubs fitted by strength welding, either in line or in staggered formation, the effective diameter of holes is to be taken as:

$$d_e = d_a - \frac{A}{t}$$

where

d_e = the equivalent diameter of the hole, in mm

d_a = the actual diameter of the hole, in mm

t = the thickness of the shell, in mm

A = the compensating area provided by each tube stub and its welding fillets, in mm^2.

2.3.2 The compensating area, A, is to be measured in a plane through the axis of the tube stub parallel to the longitudinal axis of the drum or header and is to be calculated as follows, *see Figure 1.2.7 Compensation of welded tube stubs* and *Figure 1.2.8 Compensation of welded tube stubs*

- the cross-sectional area of the stub, in excess of that required by *Vol 2, Pt 8, Ch 1, 7.1 Minimum thickness* for the minimum tube thickness, from the interior surface of the shell up to a distance, b, from the outer surface of the shell;
- plus the cross-sectional area of the stub projecting inside the shell within a distance, b, from the inner surface of the shell;
- plus the cross-sectional area of the welding fillets inside and outside the shell;

where

b = $\sqrt{d_a t_b}$

t_b = actual thickness of tube stub, in mm.

2.3.3 Where the material of the tube stub has an allowable stress lower than that of the shell, the compensating cross-sectional area of the stub is to be multiplied by the ratio:

$$\frac{\text{allowable stressof stub at design metal temperature}}{\text{allowable stress of shell at design metal temperature}}$$

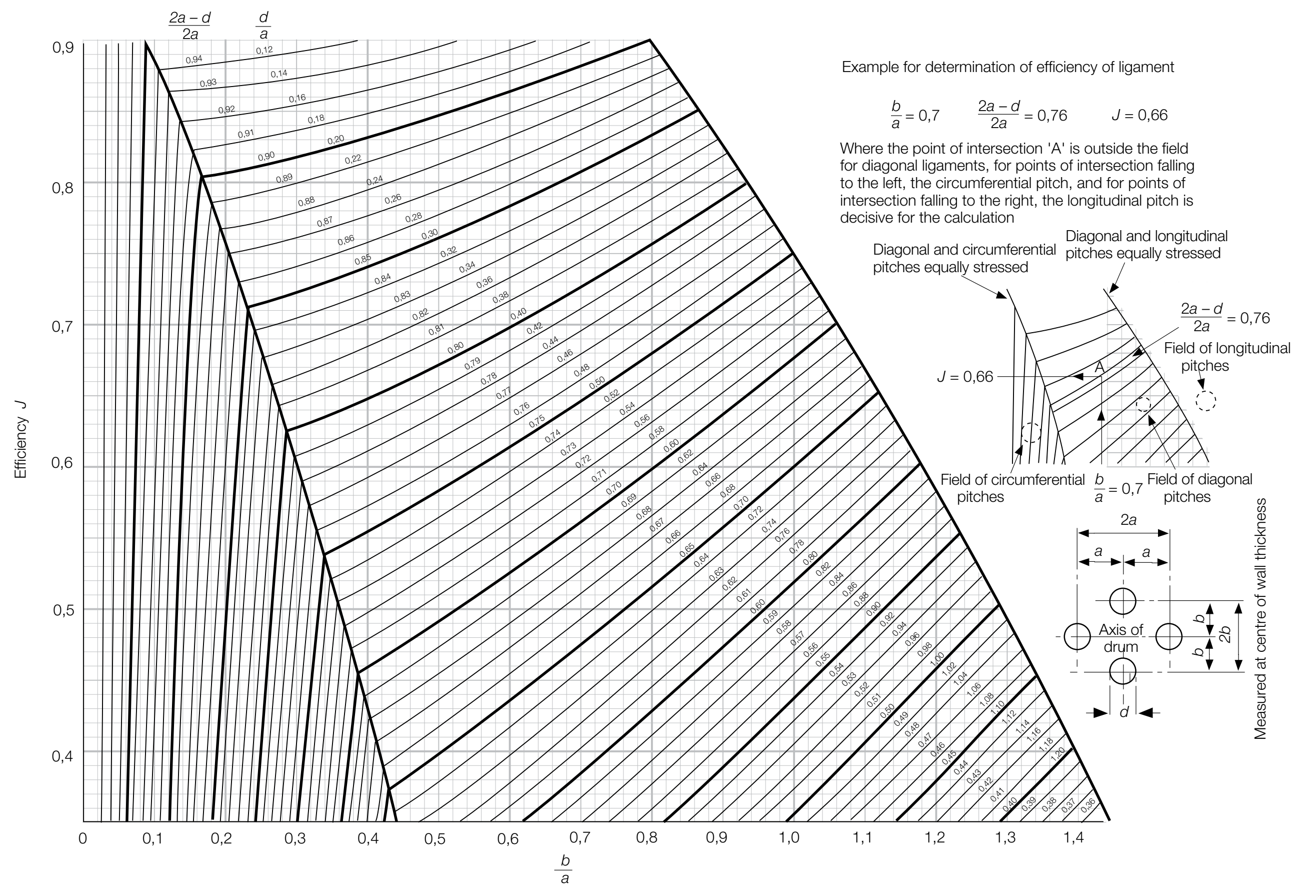
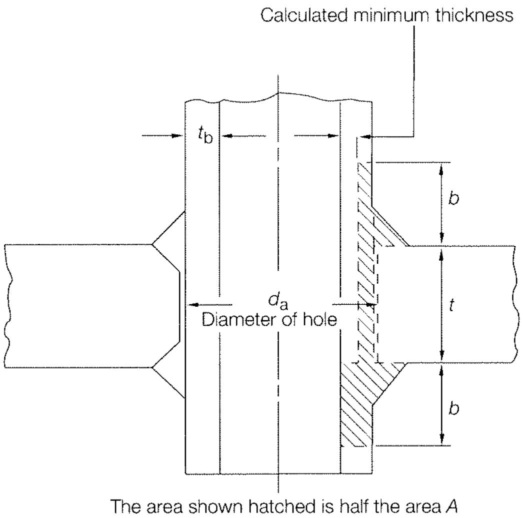
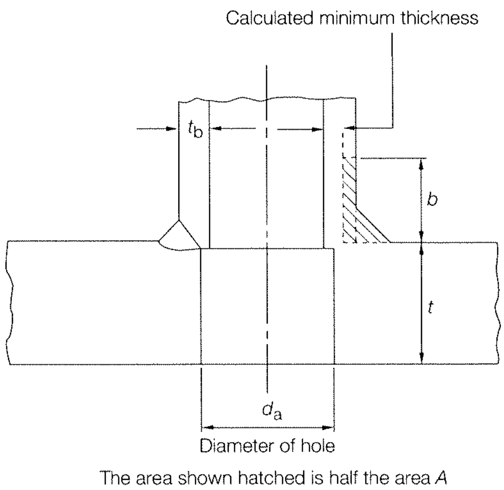


Figure 1.2.6 Efficiency of ligaments between holes



The calculated minimum thickness is to satisfy 7.1.

Figure 1.2.7 Compensation of welded tube stubs



The calculated minimum thickness is to satisfy 7.1.

Figure 1.2.8 Compensation of welded tube stubs

2.4 Unreinforced openings

2.4.1 Openings in a definite pattern, such as tube holes, may be designed in accordance with the Rules for ligaments in *Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes*, provided that the diameter of the largest hole in the group does not exceed that permitted by *Vol 2, Pt 8, Ch 1, 2.4 Unreinforced openings 2.4.2*.

2.4.2 The maximum diameter, d, of any unreinforced isolated openings is to be determined by the following formula:

$$d = 8,08\left[D_o t(1-K)\right]^{1/3} \text{ in mm}$$

The value of *K* to be used is calculated from the following formula:

$$K = \frac{pD_o}{18,2\,\sigma\,t} \text{ butisnottobetakenasgreaterthan} 0,99$$

where *p*, D_o and σ are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

t = actual thickness of shell, in mm.

2.4.3 For elliptical or oval holes, *d*, for the purposes of *Vol 2, Pt 8, Ch 1, 2.4 Unreinforced openings 2.4.2*, refers to the major axis when this lies longitudinally or to the mean of the major and minor axes when the minor axis lies longitudinally.

2.4.4 No unreinforced opening is to exceed 200 mm in diameter.

2.4.5 Holes may be considered isolated if the centre distance between two holes on the longitudinal axis of a cylindrical shell is not less than:

$$d + 1,1\sqrt{Dt} \text{ with a minimum 5d}$$

d = diameter of openings in shell (mean diameter if dissimilarly sized holes involved)

D = mean diameter of shell

t = actual thickness of shell

Where the centre distance is less than so derived, the holes are to be fully compensated.

Where two holes are offset on a diagonal line, the diagonal efficiency from *Figure 1.2.6 Efficiency of ligaments between holes* may be used to derive an equivalent longitudinal centre distance for the purposes of this paragraph.

2.5 Reinforced openings

2.5.1 Openings larger than those permitted by *Vol 2, Pt 8, Ch 1, 2.4 Unreinforced openings* are to be compensated in accordance with *Figure 1.2.9 Compensation for welded standpipes or branches in cylindrical shells*(a) or (b). The following symbols are used in *Figure 1.2.9 Compensation for welded standpipes or branches in cylindrical shells*(a) and (b):

t_s = calculated thickness of a shell without joint or opening or corrosion allowance, in mm

t_d = thickness calculated in accordance with *Vol 2, Pt 8, Ch 1, 7.1 Minimum thickness* without corrosion allowance, in mm

t_a = actual thickness of shell plate without corrosion allowance, in mm

t_b = actual thickness of standpipe without minus tolerances and corrosion allowance, in mm

t_r = thickness of added reinforcement, in mm

D_i = internal diameter of cylindrical shell, in mm

d_o = diameter of hole in shell, in mm

L = width of added reinforcement not exceeding *D*, in mm

C = $\sqrt{d_o t_b}$ in mm

D = $\sqrt{D_i t_a}$ and is not to exceed 0,5 d_o, in mm

σ = shell plate allowable stress, N/mm^2

σ_p = standpipe allowable stress, N/mm^2

σ_r = added reinforcement allowable stress, N/mm^2

σ_w = weld metal allowable stress, N/mm^2

Note σ_p, σ_r and σ_w are not to be taken as greater than σ.

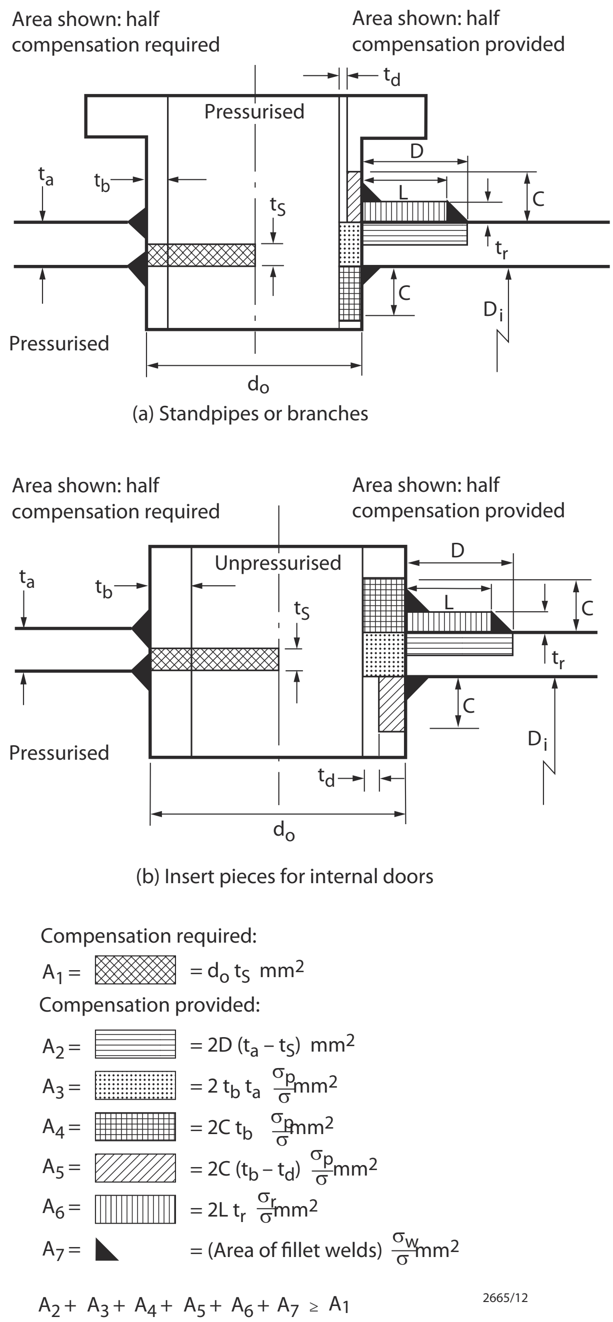


Figure 1.2.9 Compensation for welded standpipes or branches in cylindrical shells

2.5.2 For elliptical or oval holes, the dimension on the meridian of the shell is to be used for d_o in *Vol 2, Pt 8, Ch 1, 2.5 Reinforced openings 2.5.1*.

2.5.3 Compensation is to be distributed equally on either side of the centreline of the opening.

2.5.4 The welds attaching standpipes and reinforcing plates to the shell are to be of sufficient size to transmit the full strength of the reinforcing areas and all other loadings to which they may be subjected.

Section 3
Spherical shells subject to internal pressure

3.1 Minimum thickness

3.1.1 The minimum thickness of a spherical shell is to be determined by the following formula:

$$t = \frac{pR_{\mathrm{i}}}{20\,\sigma\,J - 0,5_p} + 0,75 \text{ mm}$$

where t, p, R_{i}, σ and J are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

3.1.2 The formula in *Vol 2, Pt 8, Ch 1, 3.1 Minimum thickness 3.1.1* is applicable only where the resulting thickness does not exceed half the internal radius.

3.1.3 Openings in spherical shells requiring compensation are to comply, in general, with *Vol 2, Pt 8, Ch 1, 2.5 Reinforced openings*, using the calculated and actual thicknesses of the spherical shell as applicable.

Section 4
Dished ends subject to internal pressure

4.1 Minimum thickness

4.1.1 The thickness, t, of semi-ellipsoidal and hemispherical unstayed ends, and the knuckle section of torispherical ends, dished from plate, having pressure on the concave side and satisfying the conditions listed below, is to be determined by the following formula:

$$t = \frac{pD_{\mathrm{o}}K}{20\,\alpha\,J} + 0,75 \text{ mm}$$

where t, p, D_{o}, σ and J are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

K = a shape factor, *see Vol 2, Pt 8, Ch 1, 4.2 Shape factors for dished ends* and *Figure 1.4.1 Shape factor*

4.1.2 For semi-ellipsoidal ends:

the external height, H ≥ 0,18D_{o}

where

D_{o} = the external diameter of the parallel portion of the end, in mm.

4.1.3 For torispherical ends:

- the internal radius, $R_{\mathrm{i}} \leq D_{\mathrm{O}}$
- the internal knuckle radius, $r_{\mathrm{i}} \geq 0,1\, D_{\mathrm{o}}$
- the internal knuckle radius, $r_{\mathrm{i}} \geq 3t$
- the external height, $H \geq 0,18D_{\mathrm{o}}$ and is determined as follows:

$$H = R_o - \sqrt{\left(R_{\mathrm{o}} - 0,5D_{\mathrm{o}}\right)\left(R_o + 0,5D_{\mathrm{o}} - 2r_{\mathrm{o}}\right)}$$

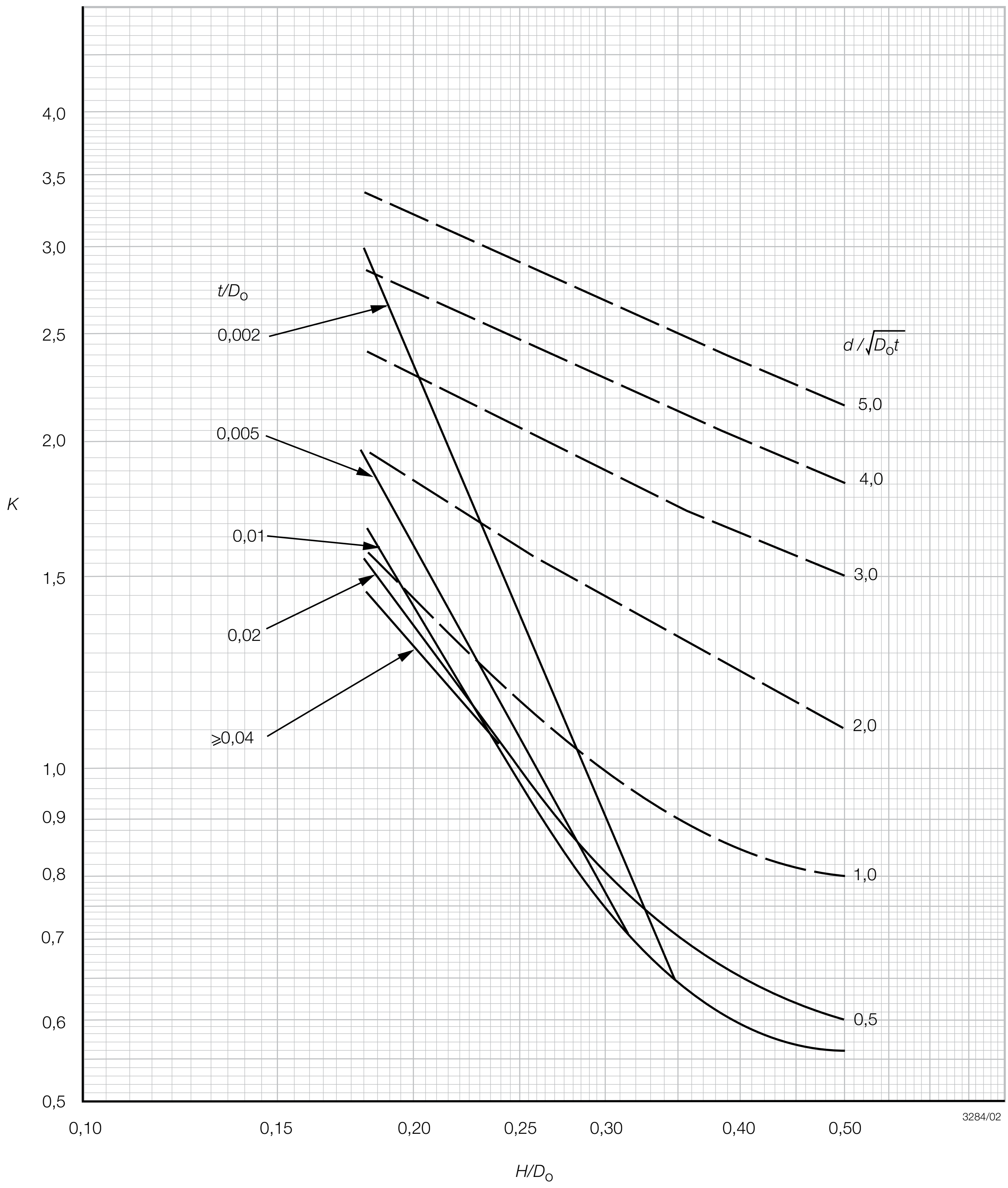


Figure 1.4.1 Shape factor

4.1.4 In addition to the formula in *Vol 2, Pt 8, Ch 1, 4.1 Minimum thickness 4.1.1* the thickness, *t*, of a torispherical head, made from more than one plate, in the crown section is to be not less than that determined by the following formula:

$$t = \frac{pR_{\text{i}}}{20\,\sigma\,J - 0,5p} + 0,75\text{ mm}$$

where t, p, R_{i}, σ and J are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

4.1.5 The thickness required by *Vol 2, Pt 8, Ch 1, 4.1 Minimum thickness 4.1.1* for the knuckle section of a torispherical head is to extend past the common tangent point of the knuckle and crown radii into the crown section for a distance not less than $0,5\sqrt{R_{\text{i}}t}$ mm, before reducing to the crown thickness permitted by *Vol 2, Pt 8, Ch 1, 4.1 Minimum thickness 4.1.4*,

where

t = the required thickness from *Vol 2, Pt 8, Ch 1, 4.1 Minimum thickness 4.1.1*

4.1.6 In all cases, H is to be measured from the commencement of curvature, *see Figure 1.4.2 Typical dished ends*

4.1.7 The minimum thickness of the head, t, is to be not less than 6,0 mm.

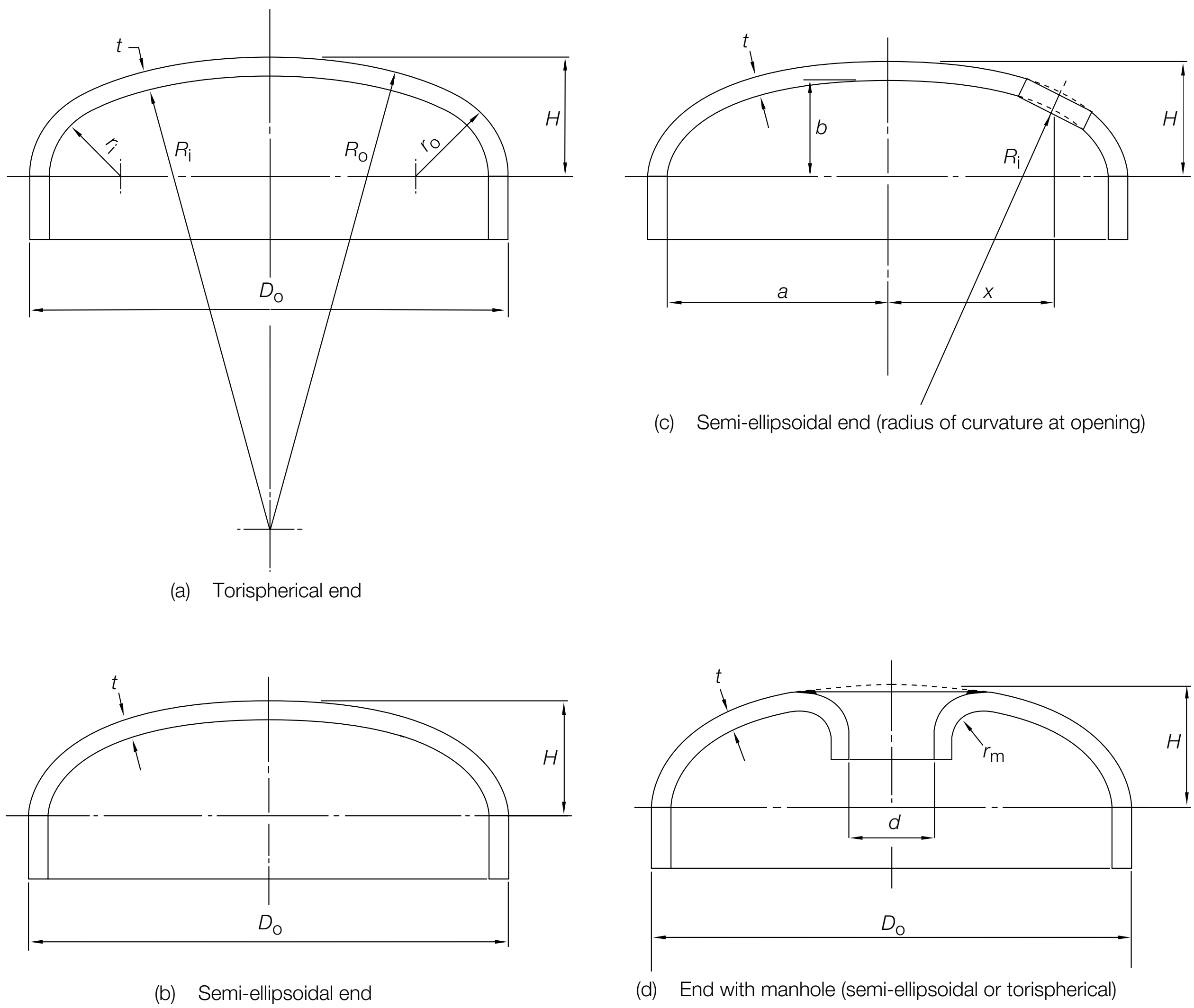


Figure 1.4.2 Typical dished ends

4.1.8 For ends which are butt welded to the drum shell, *see* 1.8, the thickness of the edge of the flange for connection to the shell is to be not less than the thickness of an unpierced seamless or welded shell, whichever is applicable, of the same diameter and material and determined by *Vol 2, Pt 8, Ch 1, 2.1 Minimum thickness*

4.2 Shape factors for dished ends

4.2.1 The shape factor, *K*, to be used in *Vol 2, Pt 8, Ch 1, 4.1 Minimum thickness 4.1.1* is to be obtained from the curves in *Figure 1.4.1 Shape factor*, and depends on the

ratio of height to diameter $\frac{H}{D_o}$.

4.2.2 The lowest curve in the series provides the factor, *K*, for plain (i.e. unpierced) ends. For lower values of $\frac{H}{D_o}$, K depends upon the ratio of thickness to diameter, $\frac{H}{D_o}$ as well as on the ratio $\frac{H}{D_o}$, and a trial calculation may be necessary to arrive at the correct value of *K*.

4.3 Dished ends with unreinforced openings

4.3.1 Openings in dished ends may be circular, obround or approximately elliptical.

4.3.2 The upper curves in *Figure 1.4.1 Shape factor* provide values of *K*, to be used in *Vol 2, Pt 8, Ch 1, 4.1 Minimum thickness 4.1.1*, for ends with unreinforced openings. The selection of the correct curve depends on the value $\frac{d}{\sqrt{D_o t}}$ and trial calculation is necessary to select the correct curve, where

d = the diameter of the largest opening in the end plate, in mm (in the case of an elliptical opening, the larger axis of the ellipse)

t = minimum thickness, after dishing, in mm

D_o = outside diameter of dished end, in mm.

4.3.3 The following requirements must in any case be satisfied:

$$\frac{t}{D_0} \leq 0,1$$

$$\frac{d}{D_o} \leq 0,7.$$

4.3.4 From *Figure 1.4.1 Shape factor* for any selected ratio of $\frac{H}{D_0}$, the curve for unpierced ends gives a value for $\frac{d}{\sqrt{D_o t}}$ as well as for *K*. Openings giving a value of $\frac{d}{\sqrt{D_o t}}$ not greater than the value so obtained may thus be pierced through an end designed as unpierced without any increase in thickness.

4.4 Flanged openings in dished ends

4.4.1 The requirements in *Vol 2, Pt 8, Ch 1, 4.3 Dished ends with unreinforced openings* apply equally to flanged openings and to unflanged openings cut in the plate of an end. No reduction may be made in end plate thickness on account of flanging.

4.4.2 Where openings are flanged, the radius, r_m, of the flanging is to be not less than 25 mm, *see Figure 1.4.2 Typical dished ends*(d). The thickness of the flanged portion may be less than the calculated thickness.

4.5 Location of unreinforced and flanged openings in dished ends

4.5.1 Unreinforced and flanged openings in dished ends are to be so arranged that the distance from the edge of the hole to the outside edge of the plate and the distance between openings are not less than those shown in *Figure 1.4.3 Opening in dished ends*.

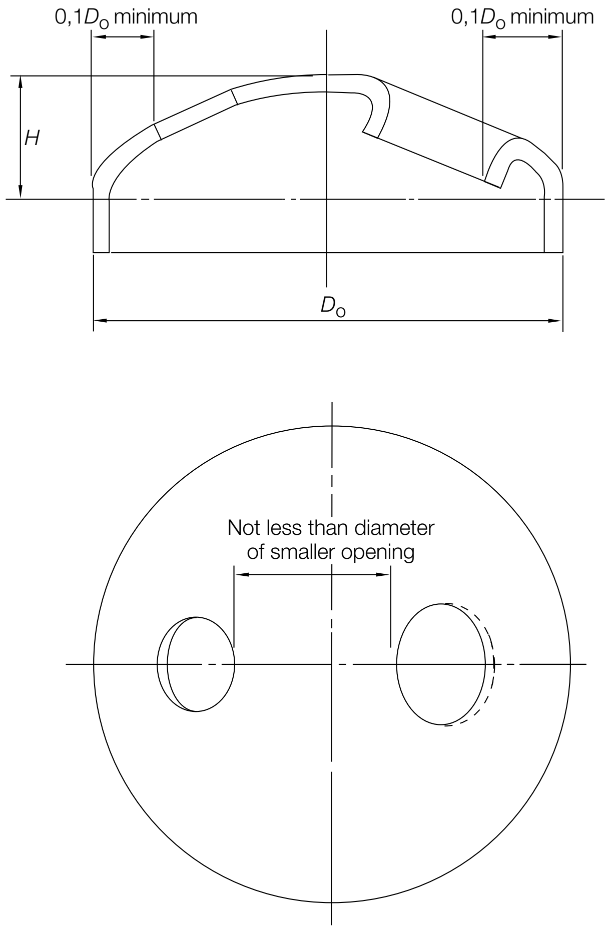


Figure 1.4.3 Opening in dished ends

4.6 Dished ends with reinforced openings

4.6.1 Where it is desired to use a large opening in a dished end of less thickness than would be required by *Vol 2, Pt 8, Ch 1, 4.3 Dished ends with unreinforced openings*, the end is to be reinforced. This reinforcement may consist of a ring or standpipe welded into the hole, or of reinforcing plates welded to the outside and/or inside of the end in the vicinity of the hole, or a combination of both methods, *see Figure 1.4.4 Limits of reinforcement* Forged reinforcements may be used.

4.6.2 Reinforcing material with the following limits may be taken as effective reinforcement:

(a) The effective width, l_1 of reinforcement is not to exceed $\sqrt{2R_i t}$ or 0,5d_o whichever is the lesser.

(b) The effective length, l_2 of a reinforcing ring is not to exceed $\sqrt{d_o t_b}$

where

R_i = the internal radius of the spherical part of a torispherical end, in mm, or

R_i = internal radius of the meridian of the ellipse at the centre of the opening, of a semi-ellipsoidal end, in mm, and is given by the following formula:

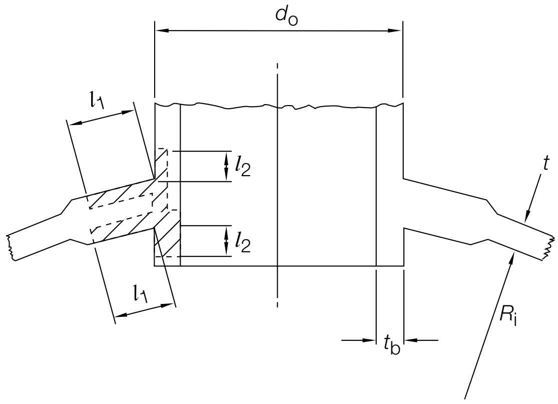
$$\frac{\left[a^4 - x^2\left(a^2 - b^2\right)\right]^{3/2}}{a^4 b}$$

where a, b and x are shown in *Figure 1.4.2 Typical dished ends*(c)

d_o = external diameter of ring or standpipe, in mm

l_1 and l_2 are shown in *Figure 1.4.4 Limits of reinforcement*

t_b = actual thickness of ring or standpipe, in mm.



$l_1 = \sqrt{2R_i t}$ or $0{,}5d_o$ whichever is the lesser
l_2 is not to exceed $\sqrt{d_o t_b}$

Figure 1.4.4 Limits of reinforcement

4.6.3 The shape factor, *K*, for a dished end having a reinforced opening can be read from *Figure 1.4.1 Shape factor* using the value obtained from:

$$\frac{d_o - \frac{A}{t}}{\sqrt{D_o t}} \text{ instead of from } \frac{d}{\sqrt{D_o t}}$$

where

A = the effective cross-sectional area of reinforcement and is to be twice the area shown shaded on *Figure 1.4.4 Limits of reinforcement*

As in *Vol 2, Pt 8, Ch 1, 4.3 Dished ends with unreinforced openings*, a trial calculation is necessary in order to select the correct curve.

4.6.4 The area shown in *Figure 1.4.4 Limits of reinforcement* is to be obtained as follows:

- Calculate the cross-sectional area of reinforcement both inside and outside the end plate within the length, l_1
- plus the full cross-sectional area of that part of the ring or standpipe which projects inside the end plate up to a distance, l_2
- plus the full cross-sectional area of that part of the ring or standpipe which projects outside the internal surface of the end plate up to a distance, l_2 and deduct the sectional area which the ring or standpipe would have if its thickness were as calculated in accordance with *Vol 2, Pt 8, Ch 1, 7.1 Minimum thickness*.

4.6.5 If the material of the ring or the reinforcing plates have an allowable stress value lower than that of the end plate, then the effective cross-sectional area, *A*, is to be multiplied by the ratio:

$$\frac{\text{allowable stress of reinforcing plate at design temperature}}{\text{allowable stress of end plate at design temperature}}$$

4.7 Torispherical dished ends with reinforced openings

4.7.1 If an opening and its reinforcement are positioned entirely within the crown section, the compensation requirements are to be as for a spherical shell, using the crown radius as the spherical shell radius. Otherwise, the requirements of *Vol 2, Pt 8, Ch 1, 4.6 Dished ends with reinforced openings* are to be applied.

Section 5
Conical ends subject to internal pressure

5.1 General

5.1.1 Conical ends and conical reducing sections, as shown in *Figure 1.5.1 Conical ends and conical reducing sections*, are to be designed in accordance with the equations given in *Vol 2, Pt 8, Ch 1, 5.2 Minimum thickness*

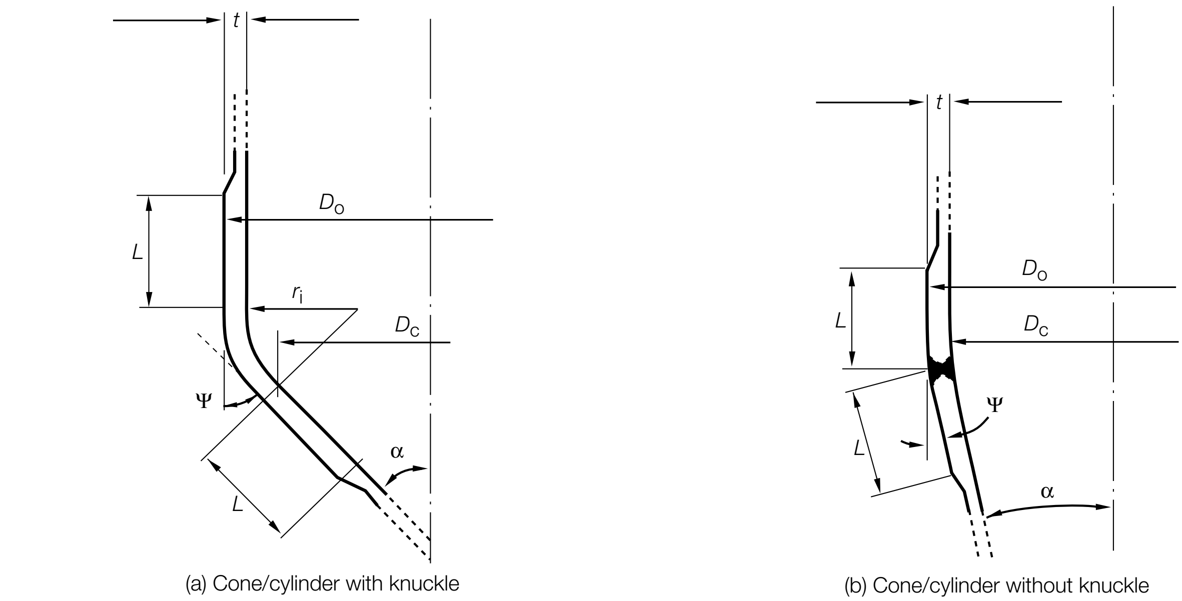


Figure 1.5.1 Conical ends and conical reducing sections

5.1.2 Connections between cylindrical shell and conical sections and ends should preferably be by means of a knuckle transition radius. Typical permitted details are shown in *Figure 1.5.1 Conical ends and conical reducing sections*. Alternatively,

conical sections and ends may be butt welded to cylinders without a knuckle radius where the change in angle of slope, ψ, between the two sections under consideration does not exceed 30°.

5.1.3 Conical ends may be constructed of several ring sections of decreasing thickness, as determined by the corresponding decreasing diameter.

5.2 Minimum thickness

5.2.1 The minimum thickness, *t*, of cylinder, knuckle and conical section at the junction and within the distance, *L*, from the junction is to be determined by the following formula:

$$t = \frac{p\,D_o K}{20\,\sigma\,J} + 0,75 \text{ mm}$$

where *t*, *p*, *σ* and *J* are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

K = a factor, taking into account the stress in the knuckle, *see Table 1.5.1 Values of K as a function of ψ and r_i / D_o*.

D_o = outside diameter, in mm, of the conical section or end, *see Figure 1.5.1 Conical ends and conical reducing sections*.

Table 1.5.1 Values of *K* as a function of ψ and r_i / D_o

ψ	Values of *K* for r_i/D_o ratios of											
	0,01	0,02	0,03	0,04	0,06	0,08	0,10	0,15	0,20	0,30	0,40	0,50
10°	0,70	0,65	0,60	0,60	0,55	0,55	0,55	0,55	0,55	0,55	0,55	0,55
20°	1,00	0,90	0,85	0,80	0,70	0,65	0,60	0,55	0,55	0,55	0,55	0,55
30°	1,35	1,20	1,10	1,00	0,90	0,85	0,80	0,70	0,65	0,55	0,55	0,55
45°	2,05	1,85	1,65	1,50	1,30	1,20	1,10	0,95	0,90	0,70	0,55	0,55
60°	3,20	2,85	2,55	2,35	2,00	1,75	1,60	1,40	1,25	1,00	0,70	0,55
75°	6,80	5,85	5,35	4,75	3,85	3,50	3,15	2,70	2,40	1,55	1,00	0,55

5.2.2 If the distance of a circumferential seam from the knuckle or junction is not to be less than *L*, then *J* is to be taken as 1,0; otherwise *J* is to be taken as the weld joint factor appropriate to the circumferential seam,

where

L = distance, in mm, from the knuckle or junction within which meridional stresses determine the required thickness, *see Figure 1.5.1 Conical ends and conical reducing sections*

= $0,5\sqrt{\frac{D_o t}{\cos\,\psi}}$

r_i = inside radius of transition knuckle, in mm, which is to be taken as $0,01D_c$ in the case of conical sections without knuckle transition.

ψ = difference between angle of slope of two adjoining conical sections, *see Figure 1.5.1 Conical ends and conical reducing sections*

5.2.3 The minimum thickness, *t*, of those parts of conical sections not less than a distance, *L*, from the junction with a cylinder or other conical section is to be determined by the following formula:

$$t = \frac{p\,D_c}{(20\,\sigma\,J - p)}\frac{1}{\cos\,\alpha} + 0,75 \text{ mm}$$

where

D_c = inside diameter, in mm of conical section or end at the position under consideration, *see Figure 1.5.1 Conical ends and conical reducing sections*

$\alpha, \alpha_1, \alpha_2$ = angle of slope of conical section (at the point under consideration) to the vessel axis, *see Figure 1.5.1 Conical ends and conical reducing sections*

5.2.4 The thickness of conical sections having an angle of inclination to the vessel axis of more than 75º is to be determined as for a flat plate.

■ *Section 6*
Standpipes and branches

6.1 Minimum thickness

6.1.1 The minimum wall thickness of standpipes and branches is to be not less than that determined by *Vol 2, Pt 8, Ch 1, 7.1 Minimum thickness* increased by the addition of a corrosion allowance of 0,75 mm, making such additions as may be necessary on account of bending, static loads and vibration. The wall thickness, however, is to be not less than:

$$t = 0,015D_o + 3,2 \text{ mm}$$

This thickness need only be maintained for a length, *L*, from the outside surface of the vessel, but need not extend past the first connection, butt weld or flange, where:

$$L = 3,5\sqrt{D_o t} \text{ mm}$$

where t and D_o are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

6.1.2 For boilers having a working pressure exceeding 50 bar and safety valves of full lift or full bore type, the thickness of the branch pipe carrying the superheater or drum safety valves is to be not less than:

$$t = \frac{1}{\sigma}\left[1,7d + \frac{DWK}{1,3d^2}\right] \text{mm}$$

where t and σ are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

d = inside diameter of branch, in mm

D = inside diameter of safety valve discharge, in mm

K = 2 for superheater safety valves

= 1 for drum safety valves.

W = total valve throughput, in kg/h

6.1.3 The offset from the centreline of the waste steam pipe to the centreline of the safety valve is not to exceed four times the outside diameter of the safety valve discharge pipe. The waste steam pipe system is to be supported and arrangements made for expansion such that no direct loading is imposed on the safety valve chests and the effects of vibration are to be minimised.

6.1.4 The pipe or header which carries the superheater safety valve is to be suitably thickened but is to be not less than the thickness required for the branch for a distance of $\sqrt{D_2 t}$ on either side of the opening

where

t = thickness required for the branch

D_2 = inside diameter of the pipe or header.

6.1.5 Except as required by *Vol 2, Pt 8, Ch 1, 6.1 Minimum thickness 6.1.4*, in no case need the wall thickness exceed the minimum shell thickness as required by *Vol 2, Pt 8, Ch 1, 2.1 Minimum thickness*, *Vol 2, Pt 8, Ch 1, 3.1 Minimum thickness* or *Vol 2, Pt 8, Ch 1, 4.1 Minimum thickness* as applicable.

6.1.6 Where a standpipe or branch is connected by screwing, the thickness is to be measured at the root of the thread.

6.1.7 For boiler, superheater or economiser tubes, the minimum thickness of the drum or the header connection or tube stub is to be calculated as part of the tube in accordance with *Vol 2, Pt 8, Ch 1, 7.1 Minimum thickness*

■ *Section 7*
Boiler tubes subject to internal pressure

7.1 Minimum thickness

7.1.1 The minimum wall thickness of straight tubes subject to internal pressure is to be determined by the following formula:

$$t = \frac{p\,D_{\mathrm{o}}}{20\,\sigma\ + p}\mathrm{mm}$$

where t, p, D_{o} and σ are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

Note 1. Provision must be made for minus tolerances where necessary and also in cases where abnormal corrosion or erosion is expected in service. For bending allowances, *see Vol 2, Pt 8, Ch 1, 7.2 Tube bending*

Note 2. Thickness is in no case to be less than the minimum shown in *Table 1.7.1 Minimum thickness of tubes*

Table 1.7.1 Minimum thickness of tubes

Nominal outside diameter of tube in mm	Minimum thickness in mm
≤ 38	1,75
> 38 ≤ 50	2,16
> 50 ≤ 70	2,40
> 70 ≤ 75	2,67
> 75 ≤ 95	3,05
> 95 ≤ 100	3,28
> 100 ≤ 125	35,0

7.1.2 The minimum thickness of boiler, superheater, reheater and economiser tubes is to be determined by using the design stress appropriate to the mean wall temperature, which will be considered to be the metal temperature. Unless it is otherwise agreed between the manufacturer and LR, the metal temperature used to decide the value of σ for these tubes is to be determined as follows:

(a) The calculation temperature for boiler tubes is to be taken as not less than the saturated steam temperature, plus 25°C for tubes mainly subject to convection heat, or plus 50°C for tubes mainly subject to radiant heat.

(b) The calculation temperature for superheater and reheater tubes is to be generally taken as not less than the steam temperature expected in the part being considered, plus 35°C for tubes mainly subject to convection heat. For tubes mainly subject to radiant heat, the calculation temperature is generally to be taken as not less than the steam temperature expected in the part being considered, plus 50°C, but the actual metal temperature expected is to be stated when submitting plans.

(c) The calculation temperature for economiser tubes is to be taken as not less than 35°C in excess of the maximum temperature of the internal fluid.

7.1.3 The minimum thickness of downcomer tubes and pipes which form an integral part of the boiler and which are not exposed to combustion gases is to comply with the requirements for steam pipes.

7.2 Tube bending

7.2.1 Where boiler, superheater, reheater and economiser tubes are bent, the resulting thickness of the tubes at the thinnest part is to be not less than that required for straight tubes, unless it can be demonstrated that the method of forming the bend results in no decrease in strength at the bend. The manufacturer is to demonstrate in connection with any new method of tube bending that this condition is satisfied.

7.2.2 Tube bending and subsequent heat treatment, where necessary, is to be carried out as to ensure that residual stresses do not adversely affect the strength of the tube for the design purpose intended.

7.3

7.3.1 For details of manholes, sight holes and doors, *see Vol 2, Pt 8, Ch 1, 14.1 Access arrangements*. For details of tube holes and fitting of tubes, *see Vol 2, Pt 8, Ch 1, 14.6 Fitting of tubes in water tube boilers*.

■ *Section 8* Headers

8.1 Circular section headers

8.1.1 The minimum thickness of circular section headers is to be calculated in accordance with the formula for cylindrical shells in *Vol 2, Pt 8, Ch 1, 2.1 Minimum thickness*.

8.2 Rectangular section headers

8.2.1 The thickness of the flat walls of rectangular section headers is to be determined at the centre of the sides, at all the lines of holes and at the corners. The minimum required shall be the greatest thickness determined by the following formula:

$$t = \frac{pn}{20\,\sigma\,J} + \sqrt{\frac{0,4Yp}{\sigma\,J_1}} + 0,75 \text{ mm}$$

where t, p and σ are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

n = one half of the internal width of the wall perpendicular to that under consideration, in mm, *see Figure 1.8.1 Rectangular section headers*

Y = a coefficient determined in accordance with *Vol 2, Pt 8, Ch 1, 8.2 Rectangular section headers 8.2.2*. In all cases if the value of Y is negative, the sign is to be ignored.

J = ligament efficiency for membrane stresses determined in accordance with *Vol 2, Pt 8, Ch 1, 8.2 Rectangular section headers 8.2.3*

J_1 = ligament efficiency for bending stresses determined in accordance with *Vol 2, Pt 8, Ch 1, 8.2 Rectangular section headers 8.2.3*.

8.2.2 The coefficient Y for use in *Vol 2, Pt 8, Ch 1, 8.2 Rectangular section headers 8.2.1* is to be determined as follows:

(a) at the centre of the side with internal width, $2m$:

$$Y = \frac{1}{3}\left(\frac{m^3 + n^3}{m + n}\right) - \frac{1}{2}m^2$$

where

m = one half of the internal width of the wall under consideration, in mm, *see Figure 1.8.1 Rectangular section headers*(b)

(b) at a line of holes parallel to the longitudinal axis of the header on the wall of width, $2m$:

$$Y = \frac{1}{3}\left(\frac{m^3 + n^3}{m + n}\right) - \frac{m^2 + b^2}{2}$$

where

b = distance from the centre of the holes to the centre line of the wall, in mm, *see Figure 1.8.1 Rectangular section headers*(a)

(c) to check the effect of the off-set on a staggered hole arrangement where the holes are positioned equidistant from the centre line of the wall:

$$Y = cos\ \alpha \left\{ \frac{1}{3}\left(\frac{m^3 + n^3}{m + n} \right) - \frac{m^2}{2} \right\}$$

where

α = the angle subtended by the diagonal ligament on the longitudinal ligament, *see Figure 1.8.1 Rectangular section headers*(a)

(d) at the corners:

$$Y = \frac{1}{3}\left(\frac{m^3 + n^3}{m + n} \right)$$

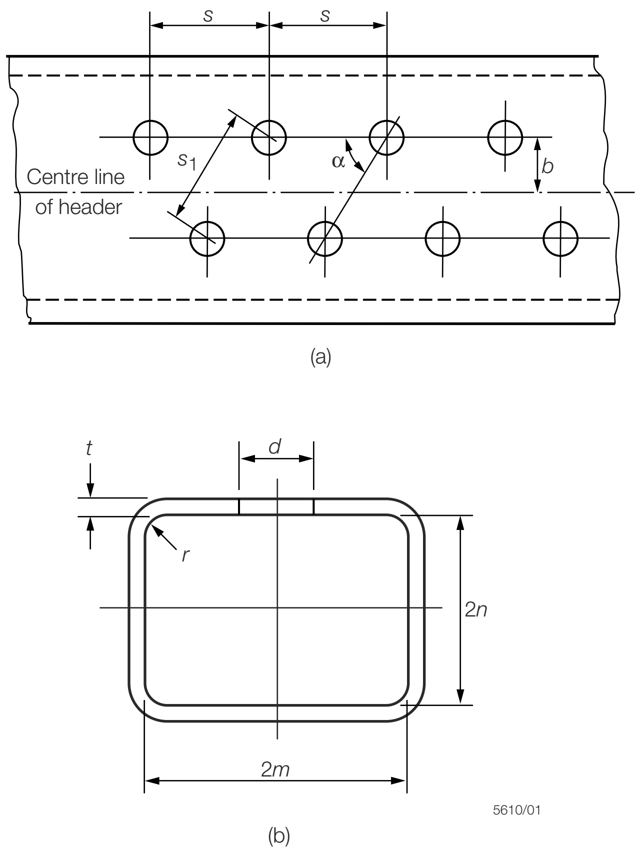


Figure 1.8.1 Rectangular section headers

8.2.3 The ligament efficiencies, J and J_1, are to be determined as follows:

(a) for a line of holes parallel to the longitudinal axis of the header:

$$J = \frac{s - d}{s}$$

(b) for the diagonals:

$$J = \frac{s_1 - d}{s_1}$$

(c) for a line of holes parallel to the longitudinal axis of the header:

$$J_1 = \frac{s - d}{s} \text{ when d} < 0,6\text{m}$$

or

$$J_1 = \frac{s - 0,6m}{s} \text{ when d} \geq 0,6\text{m}$$

(d) for the diagonals:

$$J_1 = \frac{s_1 - d}{s_1} \text{ when d} < 0,6\text{m}$$

or

$$J_1 = \frac{s_1 - 0,6m}{s_1} \text{ when d} \geq 0,6\text{m}$$

where

d = diameter of the hole in the header, in mm

m, s and s_1, in mm, are as shown in *Figure 1.8.1 Rectangular section headers*

8.2.4 In the case of elliptical holes the value of d to be used in the equations for J and J_1 is to be the inside dimension of the hole measured parallel to the longitudinal axis of the header. For evaluating the two limiting values of d in the equations for d_1, the value of d is to be the inside dimension of the hole measured perpendicular to the longitudinal axis of the header.

8.2.5 The internal corner radius, r, is to be not less than one third of the mean of the nominal thicknesses of the two sides, but in no case to be less than 6,5 mm.

8.3 Toroidal furnace headers

8.3.1 The minimum thickness of a toroidal header forming the lower end of a waterwall furnace, and supporting the weight of the boiler and water, is to be determined by the following formula:

$$t = A + \sqrt{A^2 + \frac{4M}{JS\ \sigma}} + 0,75 \text{ mm}$$

where

$$A = \frac{pr}{30J\,\sigma} \text{ mm}$$

t, p and σ are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

d_e = equivalent diameter of the tube hole in accordance with *Vol 2, Pt 8, Ch 1, 2.3 Compensating effect of tube stubs*

r = inside radius of toroid circular cross-section, in mm, *see Figure 1.8.2 Toroidal furnace headers*

J = ligament efficiency of tube holes around toroid

$= \dfrac{S - d_e}{S}$

S = pitch of tubes around the toroid, in mm

$M = \dfrac{Wr}{3} - \dfrac{pd2\,r}{40}$ Nmm

where

W = imposed loading on each water wall tube due to the weight of the boiler and water, in N

d = minimum diameter of the tube hole in the toroid, in mm

The calculation is to be performed at design pressure using the allowable stress at saturation temperature, and also at zero pressure using the allowable stress at 100°C.

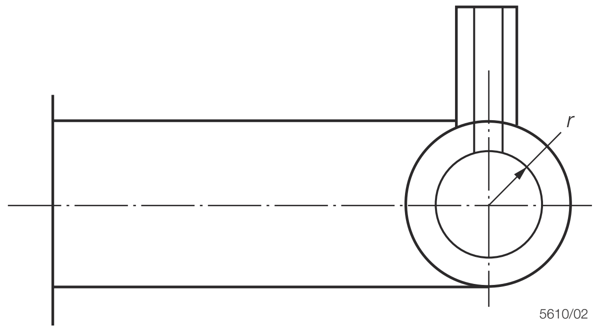


Figure 1.8.2 Toroidal furnace headers

8.4 Header ends

8.4.1 The shape and thickness of ends forged integrally with the bodies of headers are to be the subject of special consideration.

8.4.2 Where sufficient experience of previous satisfactory service of headers with integrally forged ends cannot be shown, the suitability of a proposed form of end is to be proved in accordance with the provisions of *Vol 2, Pt 8, Ch 1, 1.10 Pressure parts of irregular shape*

8.4.3 Ends attached by welding are to be designed as follows:

Dished ends: these are to be in accordance with *Vol 2, Pt 8, Ch 1, 4.1 Minimum thickness*

Flat ends: the minimum thickness of flat end plates is to be determined by the following formula:

$$t = d_{\mathrm{i}} \sqrt{\frac{p\,C}{\sigma}} + 0,75 \text{ mm}$$

where p and σ are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

t = minimum thickness of end plate, in mm

d_{i} = internal diameter of circular header or least width between walls of rectangular header, in mm

C = a constant depending on method of end attachment, *see Figure 1.8.3 Typical methods of attachment of header end closures*.

For end plates welded as shown in *Figure 1.8.3 Typical methods of attachment of header end closures*(a):

C = 0,019 for circular headers

= 0,032 for rectangular headers.

For end plates welded as shown in *Figure 1.8.3 Typical methods of attachment of header end closures*(b) and (c):

C = 0,028 for circular headers

= 0,040 for rectangular headers.

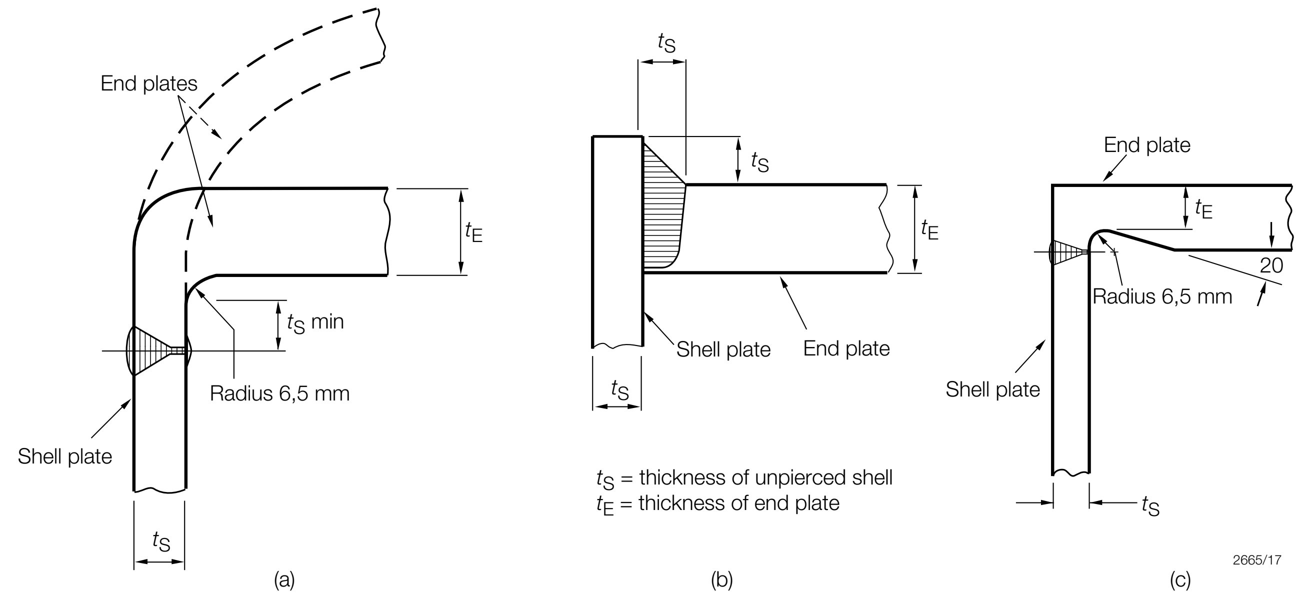


Figure 1.8.3 Typical methods of attachment of header end closures

8.4.4 Where flat end plates are bolted to flanges attached to the ends of headers, the flanges and end plates are to be in accordance with recognised pipe flange standards.

8.4.5 Openings in flat plates are to be compensated in accordance with *Figure 1.2.9 Compensation for welded standpipes or branches in cylindrical shells*(a) or (b), with the value of A_1 the compensation required, calculated as follows:

$$A_1 = \frac{d_o}{2,4} t_f \text{ mm}^2$$

where

d_o = diameter of hole in flat plate, in mm

t_f = required thickness of the flat plate in the area under consideration, in mm, calculated in accordance with *Vol 2, Pt 8, Ch 1, 8.4 Header ends 8.4.3* or *Vol 2, Pt 8, Ch 1, 9.1 Stayed flat surfaces 9.1.6*, as applicable, without corrosion allowance

Limit D = 0,5d_o.

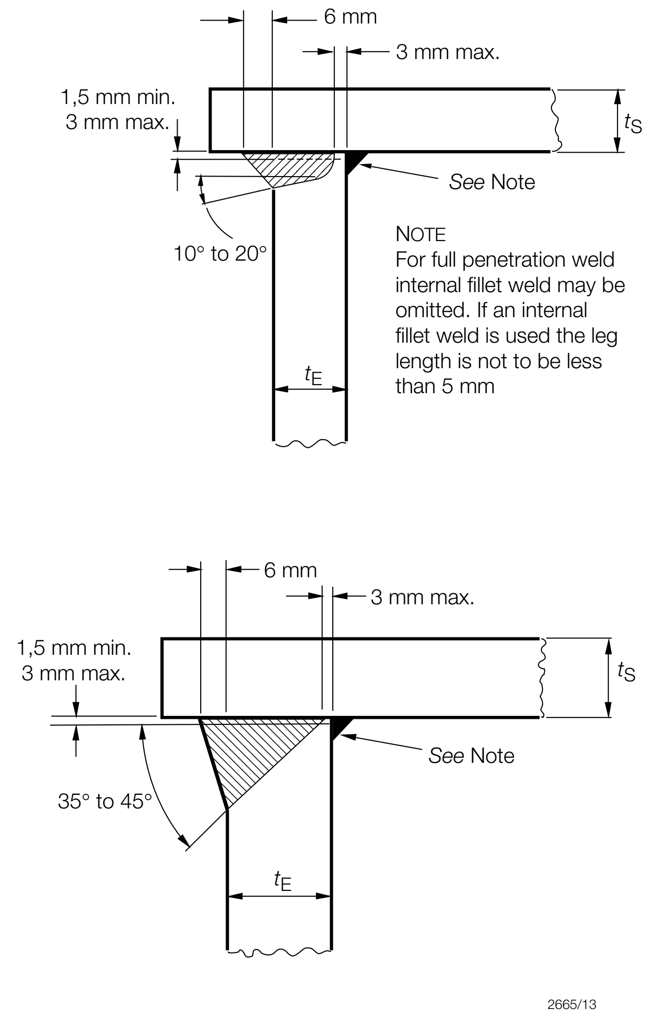
■ *Section 9* Flat surfaces and flat tube plates

9.1 Stayed flat surfaces

9.1.1 Where flat end plates are flanged for connection to the shell, the inside radius of flanging is to be not less than 1,75 times the thickness of the plate, with a minimum of 38 mm.

9.1.2 Where combustion chamber or firebox plates are flanged for connection to the wrapper plate, the inside radius of flanging is to be equal to the thickness of the plate, with a minimum of 25 mm.

9.1.3 Where unflanged flat plates are connected to the shell by welding, typical methods of attachment are shown in *Figure 1.9.1 Typical attachment of unflanged flat end plates to shell* . Similar forms of attachment may be used where unflanged combustion chamber or firebox plates are connected to the wrapper plate by welding.



t_S = thickness of cylindrical shell
t_E = thickness of flat end

Figure 1.9.1 Typical attachment of unflanged flat end plates to shell

9.1.4 Where the flange curvature is a point of support, this is to be taken at the commencement of curvature, or at a line distant 3,5 times the thickness of the plate from the outside of the plate, whichever is nearer to the flange.

9.1.5 Where a flat plate is welded directly to a shell or wrapper plate, the point of support is to be taken at the inside of the shell or wrapper plate.

9.1.6 The thickness, *t*, of those portions of flat plates supported by stays and around tube nests is to be determined by the following formula:

$$t = Cd\sqrt{\frac{p}{\sigma}} + 0,75 \text{ mm}$$

where *t*, *p* and σ are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

d = diameter of the largest circle which can be drawn through at least three points of support. At least one point of support must lie on one side of any diameter of the circle.

C = a constant, dependent on the method of support as detailed in *Vol 2, Pt 8, Ch 1, 9.1 Stayed flat surfaces 9.1.7*. Where various forms of support are used, *C* is to be the mean of the values for the respective methods adopted.

9.1.7 The value of C in the formula in *Vol 2, Pt 8, Ch 1, 9.1 Stayed flat surfaces 9.1.6* is to be as follows:

(a) Where plain bar stays are strength welded into the plates as shown in *Figure 1.9.2 Typical attachment of firebox, combustion chamber stays and bar stays*

C = 0,134

(b) Where plain bar stays pass through holes in the plates and are fitted on the outside with washers as shown in *Figure 1.9.3 Typical attachment of bar stays*

C = 0,12 where the diameter of the washer is 3,5 times the diameter of the stay

C = 0,113 where the diameter of the washer is 0,67 times the pitch of the stays.

(c) Where the flat plate is flanged for attachment to the shell, flue, furnace or wrapper or, alternatively, is welded directly to shell, flue, furnace or wrapper, *see Vol 2, Pt 8, Ch 1, 9.1 Stayed flat surfaces 9.1.4* and *Vol 2, Pt 8, Ch 1, 9.1 Stayed flat surfaces 9.1.5*:

C = 0,113

(d) Where the support is a gusset stay

C = 0,134

(e) Where the support is a tube secured as shown in *Figure 1.9.4 Detail of weld for tube*

C = 0,144.

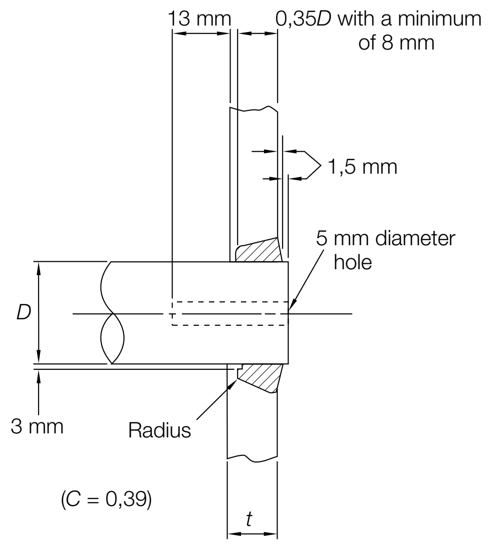
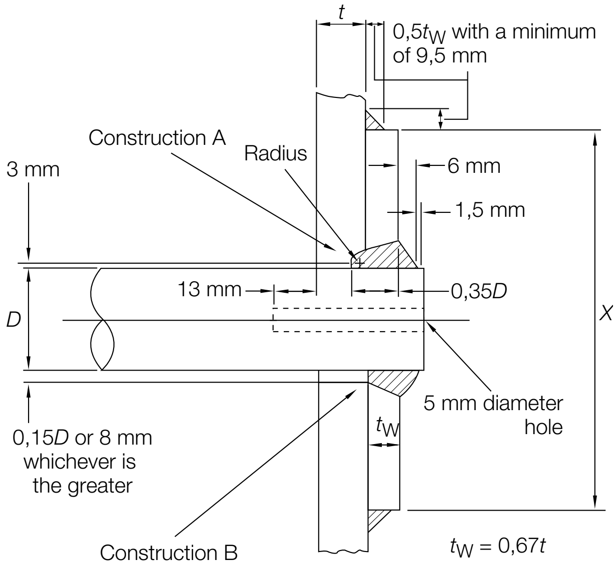


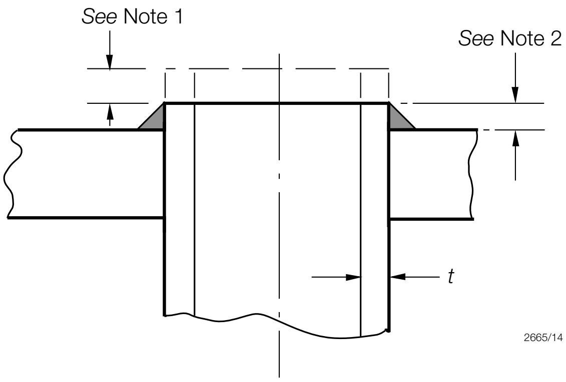
Figure 1.9.2 Typical attachment of firebox, combustion chamber stays and bar stays



Method of construction 'A' or 'B' may be used, except where t_W < 0,35D, construction 'A' is to be used.
where X = 3,5D, C = 0,12;
where X = 0,67 x pitch of stays, C = 0,113

Figure 1.9.3 Typical attachment of bar stays

9.1.8 Where tubes are fixed by expanding only, sufficient tubes welded at both ends in accordance with *Figure 1.9.4 Detail of weld for tube* are to be provided within the tube nest to comply with *Vol 2, Pt 8, Ch 1, 9.1 Stayed flat surfaces 9.1.6*, to carry the flat plate loading within the tube nest. Tubes welded in accordance with *Figure 1.9.4 Detail of weld for tube* are also to be provided in the boundary rows in sufficient numbers to carry the flat plate loading outside the tube areas.



NOTES
1. The ends of the tubes are to be dressed flush with the welds when exposed to flame. When not exposed to flame the ends of the tubes may extend a maximum of 10 mm beyond the weld.
2. 3 mm minimum, but stress in weld due to nominal flat plate load carried by the tube not to exceed 70 N/mm^2. An equivalent recessed weld may be used.
3. Weld stress area is to be based on the weld throat area.

Figure 1.9.4 Detail of weld for tube

9.1.9 In the case of small boilers with a single tube nest of expanded tubes which does not exceed an area of 0,65 m^2, welded tubes need not be fitted provided the tubes are beaded at the inlet end. In this instance the support afforded by the expanded tubes is not to be taken to extend beyond the line enclosing the outer surfaces of the tubes except that, between the outside of the nest and the attachment of the end plate to shell, there may be an unsupported width equal to the flat plate margin, as given by the formula in *Vol 2, Pt 8, Ch 1, 9.4 Flat plate margins 9.4.1*. The required tube plate thickness within such a tube nest is to be determined using the formula in *Vol 2, Pt 8, Ch 1, 9.1 Stayed flat surfaces 9.1.6*, where:

C = 0,154

d = four times the mean pitch, in mm, of the expanded tubes in the nest.

9.1.10 The thickness, t, of any tube plate in the tube area is to be not less than that required for the surrounding plate determined by *Vol 2, Pt 8, Ch 1, 9.1 Stayed flat surfaces 9.1.6* and in no case less than:

(a) 12,5 mm where the diameter of the tube hole does not exceed 50 mm, or
(b) 14 mm where the diameter of the tube hole is greater than 50 mm.

9.1.11 Alternative methods of support will be specially considered.

9.1.12 The spacing of tube holes is to be such that the minimum width, b, in mm of any ligament between tube holes is not less than:

for expanded tubes:

$b = 0{,}125d + 12{,}5$ mm

for welded tubes:

$b = 0{,}125d + 8$ mm

where

d = diameter of the hole drilled in the plate, in mm.

9.1.13 Where a flat plate has a manhole or sight hole and the opening is strengthened by flanging, the total depth, H, of the flange, measured from the outer surface of the plate, is to be not less than:

$$H = \sqrt{tW}$$

where

t = thickness of plate, in mm

H = depth of flange, in mm

W = minor axis of manhole or sight hole, in mm.

9.1.14 Where the flat top plates of combustion chambers are supported by welded-on girders, the equation in *Vol 2, Pt 8, Ch 1, 9.1 Stayed flat surfaces 9.1.6* is to apply as follows:

(a) In the case of welded-on girders provided with waterways

C = 0,144

$$d = \sqrt{X^2 + Y^2}$$

where

X = width of waterway in the girder plus the thickness of the girder, in mm

Y = pitch of girders, in mm.

(b) In the case of continuously welded-on girders

C = 0,175

d = D

where

D = distance between inside faces of girders, in mm.

9.2 Combustion chamber tube plates under compression

9.2.1 The thickness of combustion chamber tube plates under compression due to the pressure on the top plate, based on a compressive stress not exceeding 96 N/mm^2 is to be determined by the following formula:

$$t = \frac{pWs}{1930(s-d)} \text{ mm}$$

where t and p are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

d = internal diameter of the plain tubes, in mm

s = pitch of tubes, in mm, measured horizontally where tubes are chain pitched, or diagonally where the tubes are staggered pitched and the diagonal pitch is less than the horizontal pitch

W = internal width of the combustion chamber, in mm, measured from tube plate to back chamber plate.

9.3 Girders for combustion chamber top plates

9.3.1 The formula in 9.3.2 is applicable to plate girders welded to the top combustion chamber plate by means of a full penetration weld.

9.3.2 The thickness of steel plate girders supporting the tops of combustion chambers is to be determined by the following formula:

$$t = \frac{0,32p\, l^2\, s}{d^2\, R_{20}} + 0,75 \text{ mm}$$

where t and p are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

d = effective depth of girder, in mm

l = length of girder measured internally from tube plate to back chamber plate, in mm

s = pitch of the girders, in mm

R_{20} = specified minimum tensile strength of the girder plate, in N/mm^2.

9.4 Flat plate margins

9.4.1 The width of margin, b, of a flat plate which may be regarded as being supported by the shell, furnaces or flues to which the flat plate is attached is not to exceed that determined by the following formula:

$$b = C(t - 0,75)\sqrt{\frac{\sigma}{p}} \text{ mm}$$

where p and σ are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

t = thickness of the flat plate, in mm

b = width of margin, in mm

C = 3,12.

9.4.2 Where an unflanged flat plate is welded directly to the shell, furnaces or flues and it is not practicable to effect the full penetration weld from both sides of the flat plate, the constant C used in the formula in *Vol 2, Pt 8, Ch 1, 9.4 Flat plate margins 9.4.1* is to be:

C = 2,38.

9.4.3 In the case of plates which are flanged, the margin is to be measured from the commencement of curvature of flanging, or from a line 3,5 times the thickness of the plate measured from the outside of the plate, whichever is nearer to the flange.

9.4.4 Where the flat plate is not flanged for attachment to the shell, furnaces or flues, the margin is to be measured from inside of the shell or the outside of the furnaces or flues, whichever is applicable.

9.4.5 In no case is the diameter D, in mm, of the circle forming the boundary of the margin supported by the uptake of a vertical boiler to be greater than determined by the following formula:

$$D = \sqrt{\frac{345A}{p} + d^2}$$

where p is as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

d = external diameter of uptake, in mm

d_i = internal diameter of uptake, in mm

A = cross-sectional area of the uptake tube material,

$$\text{i.e.} \frac{\pi}{4}\left(\mathrm{d}^2 - \mathrm{d}^2_{\mathrm{i}}\right) \mathrm{mm}^2$$

Section 10
Flat plates and ends of vertical boilers

10.1 Tube plates of vertical boilers

10.1.1 Where vertical boilers have a nest or nests of horizontal tubes, so that there is direct tension on the tube plates due to the vertical load on the boiler ends or to their acting as horizontal ties across the shell, the thickness of the tube plates in way of the outer rows of tubes is to be determined by the following formula:

$$t = \frac{pD}{5J\,R_{20}} + 0,75 \text{ mm}$$

where t and p are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

D = twice the radial distance of the centre of the outer row of tube holes from the axis of the shell, in mm

J = efficiency of ligaments between tube holes in the outer vertical rows (expressed as a fraction)

= $\frac{s-d}{s}$

R_{20} = specified minimum tensile strength of tube plate, in N/mm^2

where

d = diameter of tube holes, in mm

s = vertical pitch of tubes, in mm.

10.1.2 Each alternate tube in the outer vertical rows of tubes is to be a tube welded at both ends as shown in *Figure 1.9.4 Detail of weld for tube*. Further, the arrangement of tubes in the nests is to be such that the thickness of the tube plates meets the requirements of *Vol 2, Pt 8, Ch 1, 9.1 Stayed flat surfaces*.

10.1.3 Where the vertical height of the tube plates between the top and bottom shelves exceeds 0,65 times the internal diameter of the boiler, the staying of the tube plates, and the scantlings of the tube plates and shell plates to which the sides of the tube plates are connected, will require to be specially considered. It is recommended, however, that for this type of boiler the

vertical height of the tube plates between the top and bottom shelves should not exceed 1,25 times the internal diameter of the boiler.

10.2 Horizontal shelves of tube plates forming part of the shell

10.2.1 For vertical boilers of the type referred to in *Vol 2, Pt 8, Ch 1, 10.1 Tube plates of vertical boilers*, in order to withstand vertical load due to pressure on the boiler ends, the horizontal shelves of the tube plates are to be supported by gussets in accordance with the following formula:

$$C = \frac{AD_{\text{i}}p}{t}$$

where

p = design pressure, in bar

t = thickness of the tube plate, in mm

A = maximum horizontal dimension of the shelf from the inside of the shell plate to the outside of the tube plate, in mm

D_{i} = inside diameter of the boiler, in mm.

10.2.2 For the combustion chamber tube plate the minimum number of gussets is to be:

1 gusset, where C exceeds 255 000

2 gussets, where C exceeds 350 000

3 gussets where C exceeds 420 000.

10.2.3 For the smokebox tube plate the minimum number of gussets is to be:

1 gusset where C exceeds 255 000

2 gussets where C exceeds 470 000.

10.2.4 The shell plates to which the sides of the tube plates are connected are to be not less than 1,6 mm thicker than is required by the formula applicable to shell plates with continuous circularity, and where gussets or other stays are not fitted to the shelves, the strength of the parts of the circumferential seams at the top and bottom of these plates from the outside of one tube plate to the outside of the other, is to be sufficient to withstand the whole load on the boiler end with a factor of safety of not less than 4,5 related to R_{20} (where R_{20} is the specified minimum tensile strength of the shell plates, in N/mm^2).

10.3 Dished and flanged ends for vertical boilers

10.3.1 The minimum thickness, t, of dished and flanged ends for vertical boilers which are subject to pressure on the concave side and are supported by central uptakes is to be determined by the following formula:

$$t = \frac{pRi}{13\,\sigma} + 0,75 \text{ mm}$$

where t, p, R_{i} and σ are as defined in *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*

10.3.2 The inside radius of curvature, R_{i}, of the end plate is to be not greater than the external diameter of the cylinder to which it is attached.

10.3.3 The inside knuckle radius, r_{i}, *see Figure 1.4.2 Typical dished ends*(a), of the arc joining the cylindrical flange to the spherical surface of the end is to be not less than four times the thickness of the end plate, and in no case less than 65 mm.

10.3.4 The inside radius of curvature of flange to uptake is to be not less than twice the thickness of the end plate, and in no case less than 25 mm.

10.3.5 If the dished end has a manhole, the opening is to be strengthened by flanging. The total depth, H, of the flange, measured from the outer surface of the plate on the minor axis, is to be not less than:

$$H = \sqrt{t\,W}$$

where

t = thickness of the flange, in mm

H = depth of flange, in mm

W = minor axis of the manhole, in mm.

10.4 Flat crowns of vertical boilers

10.4.1 The minimum thickness of flat crown plates of vertical boilers is to be determined as in *Vol 2, Pt 8, Ch 1, 9.1 Stayed flat surfaces*; *d* and *C* are defined as follows:

Where the crown is supported by an uptake only,

d = diameter, in mm, of the largest circle which can be drawn between the connections to the shell or firebox and uptake, *see Vol 2, Pt 8, Ch 1, 9.1 Stayed flat surfaces 9.1.1* to *Vol 2, Pt 8, Ch 1, 9.1 Stayed flat surfaces 9.1.5*

C = 0,161

Where bar stays are fitted in accordance with *Vol 2, Pt 8, Ch 1, 9.1 Stayed flat surfaces 9.1.6* and *Vol 2, Pt 8, Ch 1, 9.1 Stayed flat surfaces 9.1.7*,

d = diameter of the largest circle which can be drawn through at least three points of support, in mm

C = the mean of the values for the respective points of support through which the circle passes.

■ *Section 11*
Furnaces subject to external pressure

11.1 Maximum thickness

11.1.1 Furnaces, plain or corrugated, are not to exceed 22,5 mm in thickness.

11.2 Corrugated furnaces

11.2.1 The minimum thickness, *t*, of corrugated furnaces is to be determined by the following formula:

$$t = \frac{pD_o}{C}$$

where *p* is as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

t = thickness of the furnace plate measured at the bottom of the corrugations, in mm

C = 1060 for Fox, Morison and Deighton corrugations

= 1130 for Suspension Bulb corrugations

D_o = external diameter of the furnace measured at the bottom of the corrugations, in mm.

11.3 Plain furnaces, flue sections and combustion chamber bottoms

11.3.1 The minimum thickness, *t*, between points of substantial support, of plain furnaces or furnaces strengthened by stiffening rings, of flue sections and of the cylindrical bottoms of combustion chambers is to be determined by the following formulae, the greater of the two thicknesses obtained being taken:

$$t = \frac{pD_o(L + 610)}{102\,400} + 0,75 \text{ mm}$$

$$t = \frac{C\,p\,D_o}{1100} + \frac{L}{320} + 0{,}75 \text{ mm}$$

where t and p are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

C = $\frac{2x}{x+\sigma}$ or 0,85 whichever is the greater

D_o = external diameter of the furnace, flue or combustion chamber, in mm

L = length of section between the centres of points of substantial support, in mm

x and σ are as defined in *Vol 2, Pt 8, Ch 1, 11.7 Dished and flanged ends for unsupported vertical boiler furnaces 11.7.1*.

11.3.2 Where stiffeners are used for strengthening plain cylindrical furnaces, or combustion chambers, the second moment of area, I, of the stiffener is to be determined by the following formula:

$$I = \frac{p\,D_o{}^3 L}{13{,}3 \times 10^6} \text{mm}^4$$

where p is as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

D_o = external diameter of the furnace flue or combustion chamber, in mm

L = length of section between the centres of points of substantial support, in mm

For proportion of stiffening rings, *see Figure 1.11.1 Furnace, flue and combustion chamber stiffeners*.

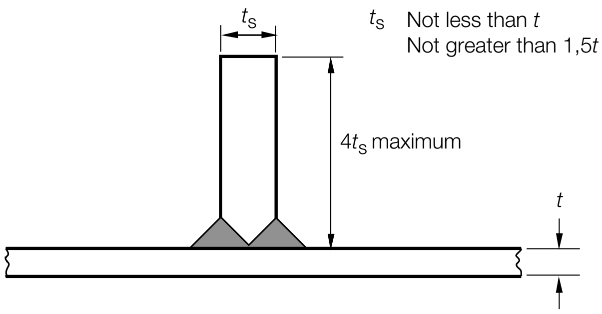


Figure 1.11.1 Furnace, flue and combustion chamber stiffeners

11.4 Plain furnaces of vertical boilers

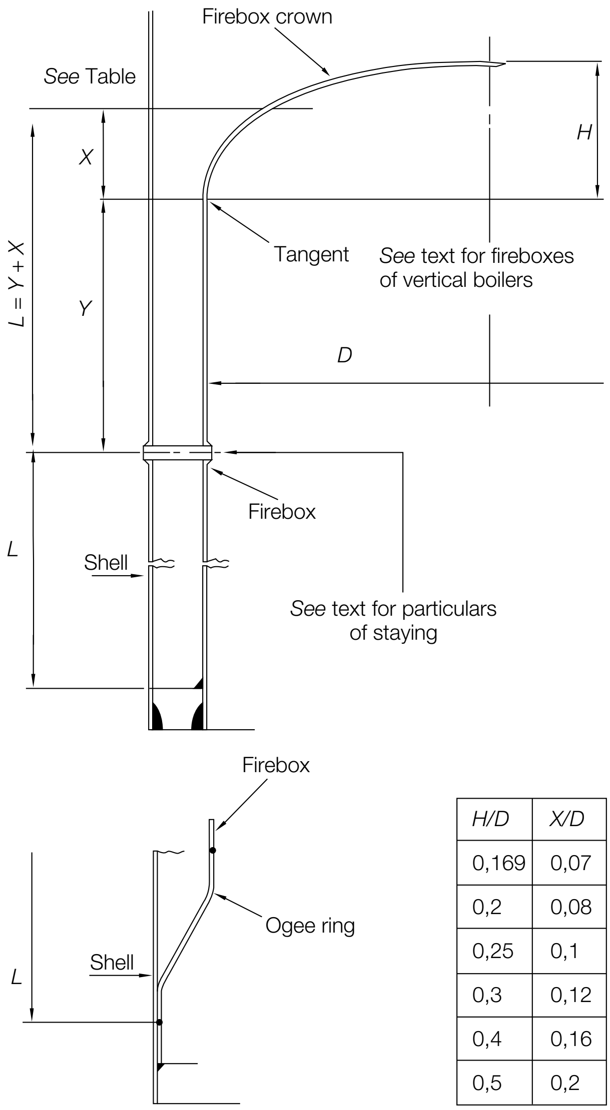
11.4.1 The thickness of plain furnaces not exceeding 2000 mm in external diameter is to be determined by the formulae given in *Vol 2, Pt 8, Ch 1, 11.3 Plain furnaces, flue sections and combustion chamber bottoms 11.3.1*, the greater of the two thicknesses being taken:

where

D_o = external diameter of the furnace, in mm. Where the furnace is tapered, the diameter to be taken for calculation purposes is to be the mean of that at the top and that at the bottom where it meets the substantial support from flange, ring or row of stays

L = effective length, in mm, of the furnace between the points of substantial support as indicated in *Figure 1.11.2 Effective length, L, for use in 11.4*

11.4.2 For furnaces under 760 mm in external diameter, the thickness is to be not less than 8 mm, and for furnaces 760 mm in external diameter and over, the thickness is to be not less than 9,5 mm.



H/D	*X/D*
0,169	0,07
0,2	0,08
0,25	0,1
0,3	0,12
0,4	0,16
0,5	0,2

Figure 1.11.2 Effective length, *L*, for use in 11.4

11.4.3 A circumferential row of stays connecting the furnace to the shell will be considered to provide substantial support to the furnace, provided that:

- The diameter of the stay is not less than 22,5 mm or twice the thickness of the furnace, whichever is the greater.
- The pitch of the stays at the furnace does not exceed 14 times the thickness of the furnace.

11.5 Hemispherical furnaces

11.5.1 The minimum thickness, *t*, of unsupported hemispherical furnaces subject to pressure on the convex surface is to be determined by the following formula:

$$t = \frac{Cp\,Ro}{608} + 0{,}75 \text{ mm}$$

where *t* and *p* are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

x and σ are as defined in *Vol 2, Pt 8, Ch 1, 11.7 Dished and flanged ends for unsupported vertical boiler furnaces 11.7.1*

C = $\dfrac{2x}{x+\sigma}$ or 0,85, whichever is the greater

R_o = outer radius of curvature of the furnace, in mm.

11.5.2 In no case is the maximum thickness to exceed 22,5 mm, or the ratio $\dfrac{R_o}{t-0,75}$ to exceed 100.

11.6 Dished and flanged ends for supported vertical boiler furnaces

11.6.1 The minimum thickness, *t*, of dished and flanged ends for vertical boiler furnaces that are subject to pressure on the convex side and are supported by central uptakes, is to be determined by the following formula:

$$t = \frac{p\,R_o}{10\,\sigma} + 0,75 \text{ mm}$$

where *t*, *p*, R_o and σ are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

11.6.2 The inside radius of dishing and flanging are to be as required by *Vol 2, Pt 8, Ch 1, 10.3 Dished and flanged ends for vertical boilers*

11.7 Dished and flanged ends for unsupported vertical boiler furnaces

11.7.1 The minimum thickness, *t*, of dished and flanged ends for vertical boiler furnaces that are subject to pressure on the convex side and are without support from stays of any kind, is to be determined by the following formula, but is in no case to be less than the thickness of the firebox:

$$t = \frac{C\,p\,R_o}{660} + 0,75 \text{ mm}$$

where *t* and *p* are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

x = specified minimum lower yield stress or 0,2 per cent proof stress in N/mm^2 at a temperature 90°C above the saturated steam temperature corresponding to the design pressure for carbon and carbon manganese steel with a specified minimum tensile strength of 400 N/mm^2

C = $\dfrac{2x}{x+\sigma}$ or 0,85 whichever is the greater

R_o = outside radius of the crown plate, in mm

= $\left(\text{in no case is } \dfrac{R_o}{t} \text{ to exceed } 88\right)$

σ = specified minimum lower yield stress or 0,2 per cent proof stress in N/mm^2 at a temperature 90°C above the saturated steam temperature corresponding to the design pressure for the steel actually used.

11.7.2 The inside radius of curvature, R_i, of the end plate is to be not greater than the external diameter of the cylinder to which it is attached.

11.7.3 The inside knuckle radius, r_i, *see Figure 1.4.2 Typical dished ends*(a), of the arc joining the cylindrical flange to the spherical surface of the end is to be not less than four times the thickness of the end plate and in no case less than 65 mm.

11.8 Ogee rings

11.8.1 The minimum thickness, *t*, of the ogee ring which connects the bottom of the furnace to the shell of a vertical boiler and sustains the whole vertical load on the furnace is to be determined by the following formula:

$$t = \sqrt{\frac{pD_i\left(D_i - D_o\right)}{9\,900}} + 0,75 \text{ mm}$$

where *t* and *p* are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

D_i = inside diameter of boiler shell, in mm

D_o = outside diameter of the lower part of the furnace where it joins the ogee ring, in mm.

11.8.2 Proposals to use a flat plate annular ring which connects the bottom of the furnace to the shell of a vertical boiler and sustains any unbalanced vertical load on the furnace will be the subject of special consideration.

11.9 Uptakes of vertical boilers

11.9.1 The minimum thickness, *t*, of internal uptakes of vertical boilers is to be determined by the following formulae, the greater of the two thicknesses obtained being taken:

$$t = \sqrt{\frac{pD_o(L + 610)}{102\,400}} + 4 \text{ mm}$$

$$t = \frac{pD_o}{1100} + \frac{L}{320} + 4 \text{ mm}$$

where *t* and *p* are as defined in *Vol 2, Pt 8, Ch 1, 1.2 Definition of symbols*

D_o = external diameter of uptake, in mm

L = length of uptake between the centres of points of substantial support, in mm.

Section 12
Boiler tubes subject to external pressure

12.1 Tubes

12.1.1 The thickness of tubes is to be in accordance with *Table 1.12.1 Thickness of plain tubes under external pressure* for the appropriate outside diameter and design pressure.

Table 1.12.1 Thickness of plain tubes under external pressure

Design pressure, in bar											Thickness, in mm
Outside diameter, in mm											
38	44,5	51	57	63.5	70	76	82.5	89	95	102	
—	—	—	—	—	—	—	—	—	26,9	25,2	5,89
—	—	—	—	—	—	—	26,2	24,1	22,8	21,4	5,38
—	—	—	—	—	—	24,1	22,1	20,7	19,3	17,9	4,88
—	—	—	27,6	24,8	22,8	20,7	19,3	17,9	16,6	15,9	4,47
—	29,3	25,5	22,8	20,7	18,9	17,3	15,9	14,8	13,7	12,7	4,06
26,6	22,8	20,7	17,9	15,9	14,8	13,1	12,4	11,4	10,3	9,6	3,66
20,3	16,9	14,8	13,1	12,1	11,0	9,6	8,9	8,2	7,6	6,9	3,25
14,8	12,4	10,7	9,6	8,6	7,6	—	—	—	—	—	2,95

12.1.2 Tubes may be welded at both ends, welded at the inlet end and expanded at the outlet end, or expanded at both ends. In addition to expanding, tubes may be bell mouthed or beaded at the inlet end. Where tubes are welded, the weld detail is to be as shown in *Figure 1.9.4 Detail of weld for tube* and the tubes are to be expanded into the tube plates in addition to welding, except as permitted by *Vol 2, Pt 8, Ch 1, 12.1 Tubes 12.1.3*.

12.1.3 For tubes of thickness greater than 6,0 mm, expanding in addition to welding is not required if a recessed weld of depth not less than the tube thickness is provided.

■ *Section 13* Tubes welded at both ends and bar stays for cylindrical boilers

13.1 Loads on tubes welded at both ends and bar stays

13.1.1 Each tube or bar stay is to be designed to carry its due proportion of the load on the plates which it supports.

13.1.2 For a tube or bar stay, the net area to be supported is to be the area, in mm^2, enclosed by the lines bisecting at right angles the lines joining the stay and the adjacent points of support, less the area of any tubes or stays enclosed. In the case of a tube or bar stay in the boundary rows, the support afforded by the flat plate margin, where applicable, should be taken into account. Where flat margins overlap stays are not required.

13.1.3 The thickness of tubes welded at both ends to tube plates is to be such that the longitudinal stress due to the flat plate loading does not exceed 70 N/mm^2.

13.1.4 Tubes may be welded into the boiler after postweld heat treatment has been carried out.

13.1.5 The permissible longitudinal stress in combustion chamber bar stays or similar stays where an end is heated by flame, is not to exceed 70 N/mm^2, and the diameter of this type of bar stay is not to be less than 19 mm.

13.1.6 The permissible longitudinal stress in longitudinal bar stays not subject to heating, is not to exceed 20 per cent of the minimum specified tensile strength, in N/mm^2, and the diameter of this type of bar stay is not to be less than 25 mm.

■ *Section 14* Construction

14.1 Access arrangements

14.1.1 In watertube boilers, manholes are to be provided in all drums of sufficient size to allow access for internal examination and cleaning, and for fitting and expanding the tubes. In the case of headers for water walls, superheaters or economisers, and of drums which are too small to permit entry, sight holes or mudholes sufficiently large and numerous for these purposes are to be provided.

14.1.2 Cylindrical boilers are to be provided, where possible with means for ingress to permit examination and cleaning of the inner surfaces of plates and tubes exposed to flame. Where the boilers are too small to permit this there are to be sight holes and mudholes sufficiently large and numerous to allow the inside to be satisfactorily cleaned.

14.1.3 Where the cross tubes of vertical boilers are large, there is to be a sight hole in the shell opposite to one end of each tube sufficiently large to allow the tube to be examined and cleaned. These sight holes are to be in positions accessible for that purpose.

14.1.4 Manholes in cylindrical shells should preferably have their shorter axes arranged longitudinally.

14.1.5 Doors for manholes, mudholes and sight holes are to be formed from steel plate or other approved construction, and all jointing surfaces are to be machined.

14.1.6 Doors of the internal type are to be provided with spigots which have a clearance of not more than 1,5 mm all round, i.e. the axes of the opening are not to exceed those of the door by more than 3 mm. The width of the manhole gasket seat is to be not less than 16 mm.

14.1.7 Doors of the internal type for openings not larger than 230 mm x 180 mm need be fitted with one stud only, which may be forged integral with the door. Doors for openings larger than 230 mm x 180 mm are to be fitted with two studs or bolts. The strength of the attachment to the door is to be not less than the strength of the stud or bolt.

14.1.8 The crossbars or dogs for doors are to be of steel.

14.1.9 For smaller circular openings in headers and similar fittings, an approved type of plug may be used.

14.1.10 Circular flat cover plates may be fitted to raised circular manhole frames not exceeding 400 mm diameter, and for an approved design pressure not exceeding 18 bar.

14.1.11 External circular flat cover plates are to be in accordance with a recognised National Standard.

14.2 Torispherical and semi-ellipsoidal ends

14.2.1 For typical acceptable types of attachment for dished ends to cylindrical shells, *see Figure 1.14.1 Typical attachments of dished ends to cylindrical shells*

14.2.2 Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

14.2.3 The thickness of the plates at the position of the circumferential weld is to be not less than that of an unpierced cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material, *see Vol 2, Pt 8, Ch 1, 4.1 Minimum thickness*

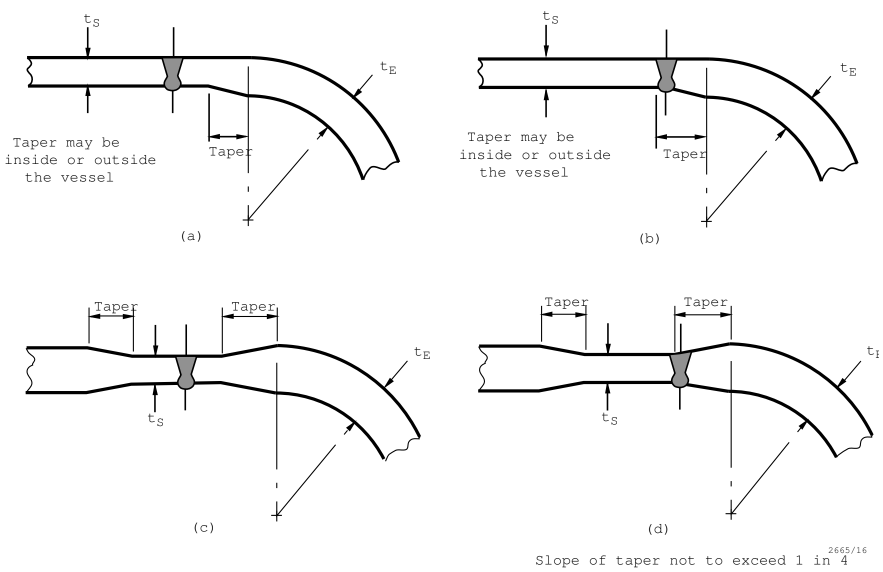


Figure 1.14.1 Typical attachments of dished ends to cylindrical shells

14.3 Hemispherical ends

14.3.1 Where hemispherical ends are butt welded to cylindrical shells, the thickness of the shell is to be reduced by taper to that of the end, and the centre of the hemisphere is to be so located that the entire tapered portion of the shell and the butt weld are within the hemisphere, *see Figure 1.14.2 Attachment of hemispherical end to cylindrical shell*.

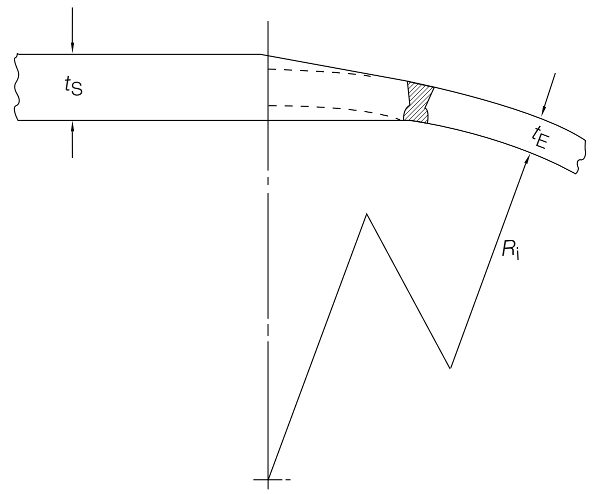


Figure 1.14.2 Attachment of hemispherical end to cylindrical shell

14.3.2 If the hemispherical end is provided with a parallel portion, the thickness of this portion is to be not less than that of a seamless or welded shell, whichever is applicable, of the same diameter and material.

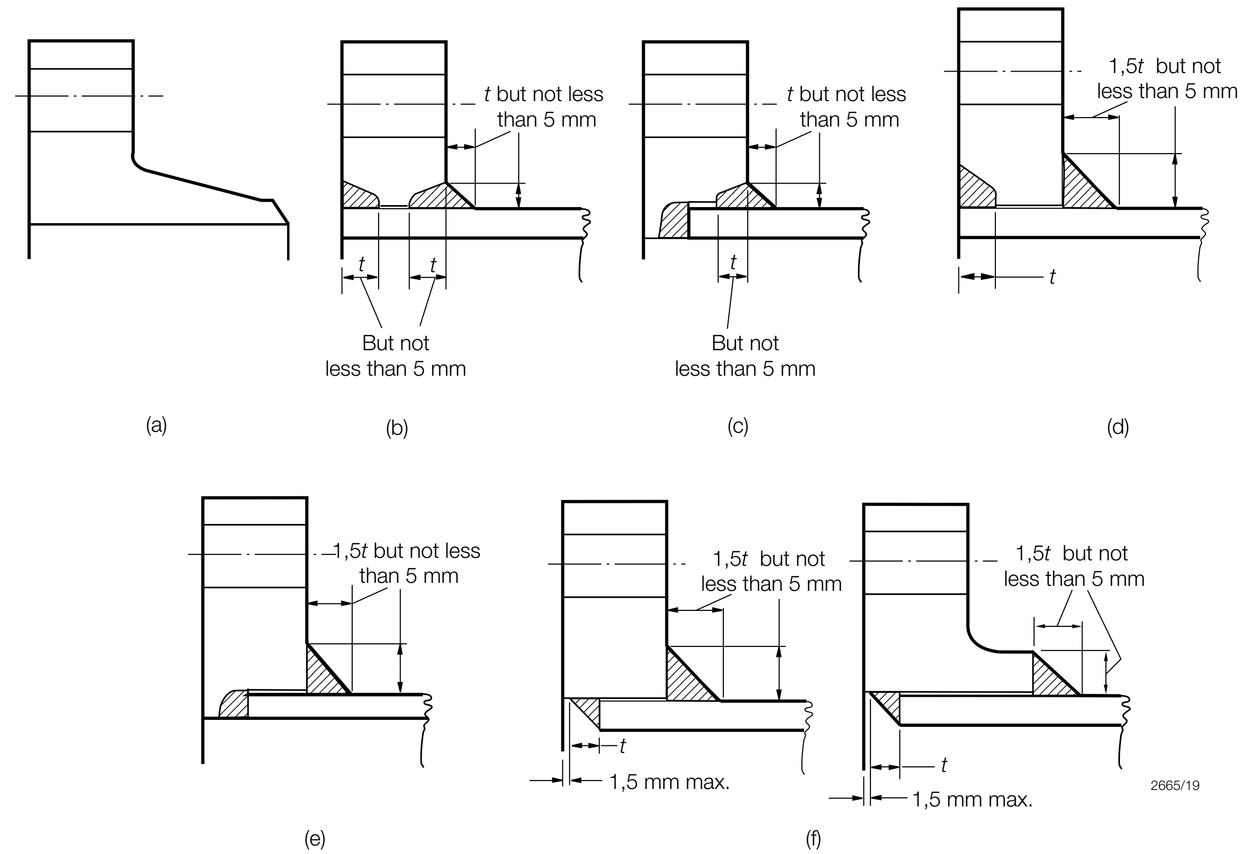
14.4 Welded-on flanges, butt welded joints and fabricated branch pieces

14.4.1 Flanges may be cut from plates or may be forged or cast. Hubbed flanges are not to be machined from plate. Flanges are to be attached to branches by welding. Alternative methods of flange attachment will be subject to special consideration.

14.4.2 The types of welded-on flanges are to be suitable for the pressure, temperature and service for which the branches are intended.

14.4.3 Flange attachments and pressure-temperature ratings in accordance with materials and design of recognised standards will be accepted.

14.4.4 Typical examples of welded-on flange connections are shown in *Figure 1.14.3 Typical examples of welded flange connections*(a) to (f), and limiting design conditions for the flange types are shown in *Table 1.14.1 Limited design conditions for flanges*. In *Figure 1.14.3 Typical examples of welded flange connections*, *t* is the minimum Rule thickness of the standpipe or branch.



't' is the minimum Rule thickness of standpipe or branch

Figure 1.14.3 Typical examples of welded flange connections

Table 1.14.1 Limited design conditions for flanges

Flange type	Maximum pressure	Maximum temperature °C	Maximum pipe o.d. mm	Minimum pipe bore mm
(a)	Pressure-temperature ratings to be in accordance with a recognised standard	No restriction	No restriction	No restriction
(b)	Pressure-temperature ratings to be in accordance with a recognised standard	No restriction	168,3 for alloy steels*	No restriction
(c)	Pressure-temperature ratings to be in accordance with a recognised standard	No restriction	168,3 for alloy steels*	75
(d)	Pressure-temperature ratings to be in accordance with a recognised standard	425	No restriction	No restriction
(e)	Pressure-temperature ratings to be in accordance with a recognised standard	425	No restriction	75
(f)	Pressure-temperature ratings to be in accordance with a recognised standard	425	No restriction	No restriction

*No restriction for carbon steels

14.4.5 Welded-on flanges are not to be a tight fit on the branch. The maximum clearance between the bore of the flange and the outside diameter of the branch is to be 3 mm at any point, and the sum of the clearances diametrically opposite is not to exceed 5 mm.

14.4.6 Where butt welds are employed in the attachment of flange type (a), or in the construction of standpipes or branch pieces, the adjacent pieces are to be matched at the bores. This may be effected by drifting, roller expanding or machining, provided the pipe wall is not reduced below the designed thickness. If the parts to be joined differ in wall thickness, the thicker wall is to be gradually tapered to that of the thinner at the butt joint.

14.4.7 Welding may be carried out by means of the shielded metal arc, inert gas metal arc, oxy-acetylene or other approved process, but in general, oxy-acetylene welding is suitable only for flange type (a) and is not to be applied to branches exceeding 100 mm diameter or 9,5 mm thick. The welding is to be carried out in accordance with the appropriate paragraphs of *Vol 2, Pt 1, Ch 4 Requirements for Fusion Welding of Pressure Vessels and Piping*.

14.4.8 Threaded sleeve joints complying with *Vol 2, Pt 7, Ch 1, 5.6 Socket weld joints 5.6.1* may be used on the steam and water piping of small oil fired package boilers of the once through coil type, used for auxiliary or domestic purposes, where the feed pump capacity limits the output.

14.5 Welded attachments to pressure vessels

14.5.1 Unless the actual thickness of the shell or end is at least twice that required by calculation for a seamless shell or end, whichever is applicable, doubling plates with well rounded corners are to be fitted in way of attachments such as lifting lugs, supporting brackets and feet, to minimise load concentrations on pressure shells and ends. Compensating plates, pads, brackets and supporting feet are to be bedded closely to the surface before being welded, and are to be provided with a 'tell-tale' hole not greater than 9,5 mm in diameter, open to the atmosphere to provide for the release of entrapped air during heat treatment of the vessel, or as means of indicating any leakage during hydraulic testing and in service. *See Vol 2, Pt 1, Ch 4 Requirements for Fusion Welding of Pressure Vessels and Piping*

14.5.2 For acceptable methods of attaching standpipes, branches, compensating plates and pads, *see Figure 1.14.4 Typical acceptable methods of attaching branches and pads*. Alternative methods of attachment may be accepted provided details are submitted for consideration.

14.5.3 Where fillet welds are used to attach standpipes or set-in pads, there are to be equal sized welds both inside and outside the vessel, *see Figure 1.14.4 Typical acceptable methods of attaching branches and pads*(a) and (l). The leg length of each of the fillet welds is to be not less than 1,4 times the actual thickness of the thinner of the parts being joined.

14.6 Fitting of tubes in water tube boilers

14.6.1 The tube holes in drums or headers are to be formed in such a way that the tubes can be effectively tightened in them. Where the tube ends are not normal to the tube plates, there is to be a neck or belt of parallel seating of at least 13 mm in depth, measured in a plane through the axis of the tube at the holes. Where the tubes are practically normal to their plates, this parallel seating is to be not less than 9,5 mm in depth.

14.6.2 Tubes are to be carefully fitted in the tube holes and secured by means of welding, expanding and belling or by other approved methods. Tubes are to project through the neck or belt of parallel seating by at least 6 mm and where they are secured from drawing out by means of bellmouthing only, the included angle of belling is to be not less than 30°.

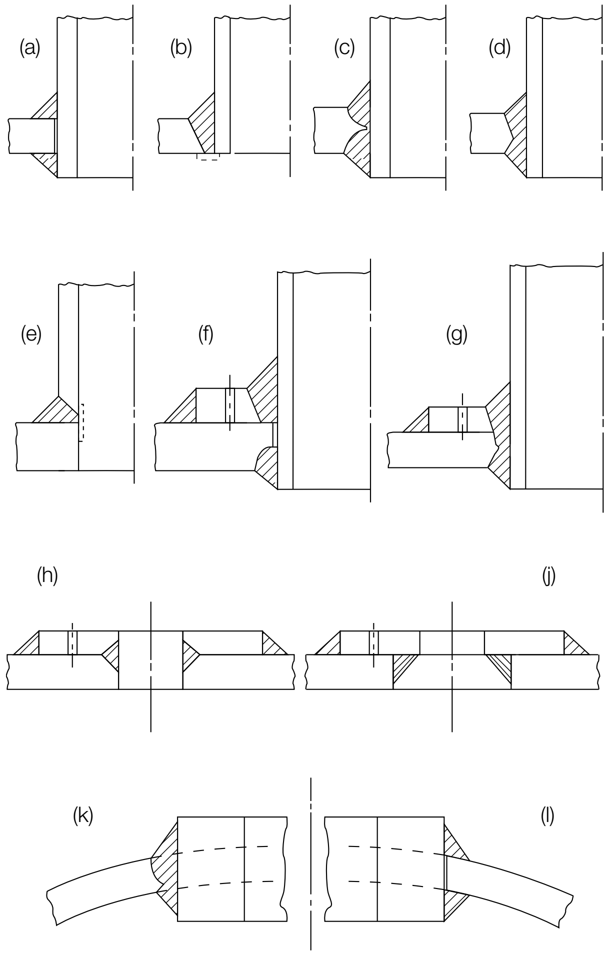


Figure 1.14.4 Typical acceptable methods of attaching branches and pads

■ Section 15
Mountings and fittings for cylindrical and vertical boilers, steam generators, pressurised thermal liquid and pressurised hot water heaters

15.1 General

15.1.1 Valves over 38 mm diameter are to be fitted with outside screws, and the covers are to be secured by bolts or studs. All valves are to be arranged to shut with a right-hand (clockwise) motion of the wheels.

15.1.2 All valves and cocks connected to the boiler are to be such that it is seen without difficulty whether they are open or shut. Where boiler mountings are secured by studs, the studs are to have a full thread holding in the plate for a length of at least one diameter.

15.1.3 Where a superheater is fitted which can be shut-off from the boiler, it is to be provided with a separate safety valve fitted with easing gear. The valve as regards construction is to comply with the regulations for ordinary safety valves, but the easing gear may be fitted to be workable from the stokehold only. The superheater is also to be fitted with a drain valve or cock to free it from water when necessary.

15.1.4 Safety valve chests and other boiler and superheater mountings subjected to pressures exceeding 13,0 bar or to steam temperatures exceeding 220°C, and boiler blow-down fittings, are to be made of steel or other approved material.

15.2 Safety valves

15.2.1 Boilers and steam generators are to be fitted with not less than two safety valves, each having a minimum internal diameter of 25 mm, but those having a total heating surface of less than 50 m^2 may have one valve not less than 50 mm diameter. Small oil fired package boilers of the once through coil type used for auxiliary or domestic purposes, where the feed pump capacity limits the output, may have one safety valve not less than 19 mm internal diameter, or two safety valves with internal diameters not less than 16 mm, provided the capacity is in accordance with *Vol 2, Pt 8, Ch 1, 15.2 Safety valves 15.2.13*

15.2.2 The valves, spindles, springs and compression screws are to be so encased and locked or sealed that the safety valves and pilot valves, after setting to the working pressure, cannot be tampered with or overloaded in service.

15.2.3 Valves are to be so designed that in the event of fracture of springs they cannot lift out of their seats.

15.2.4 Easing gear is to be provided for lifting the safety valves and is to be operable by mechanical means at a safe position from the boiler or engine room platforms.

15.2.5 Safety valves are to be made with working parts having adequate clearances to ensure complete freedom of movement.

15.2.6 Valve seats are to be effectively secured in position. Any adjusting devices which control discharge capacity are to be positively secured so that the adjustment will not be affected when the safety valves are dismantled at surveys.

15.2.7 All the safety valves of each boiler and steam generator may be fitted in one chest, which is to be separate from any other valve chest and is to be connected directly to the shell by a strong and stiff neck, the passage through which is to be of cross-sectional area not less than the aggregate area of the safety valves in the chest in the case of full lift valves, and one-half of that area in the case of other valves. For the meaning of aggregate area, *see Vol 2, Pt 8, Ch 1, 15.2 Safety valves 15.2.13*.

15.2.8 For each safety valve, an individual unrestricted drain is to be provided. The drain pipe is to be fitted to the lowest part of the discharge side of the safety valve; it is to be below the level of the valve seat and is to be independently led with a continuous fall to a place where the high temperature steam and/or condensate can discharge, visibly clear of the boilers, and where it cannot cause injury. No valves or cocks are to be fitted to these drain pipes. The bore of the drain pipes is not to be less than 19 mm. Where a drain pipe of 19 mm is impracticable, smaller drain pipes may be considered.

15.2.9 Safety valves for shell type exhaust gas steaming economisers are to incorporate fail safe features which will ensure operation of the valve even with solid matter deposits on the valve and guide, or features that will prevent the accumulation of solid matter in way of the valve and in the clearance between the valve spindle and guide. Alternatively, if the fitted valves do not incorporate the features described then a bursting disc discharging to a suitable waste steam pipe is to be fitted in addition to the valves. These bursting discs are to function at a pressure not exceeding 1,25 times the economiser approved design pressure and are to have sufficient capacity to prevent damage to the economiser when operating at its design heat input level.

15.2.10 To avoid the accumulation of solid matter deposits on the outlet side of the safety valves and bursting discs required by *Vol 2, Pt 8, Ch 1, 15.2 Safety valves 15.2.9*, the discharge pipes and safety valve/bursting disc housings are to be fitted with drainage arrangements from the lowest part, directed with continuous fall to a position clear of the economiser where it will not pose a threat to either personnel or machinery. No valves or cocks are to be fitted in the drainage arrangements. The drainage arrangements required by *Vol 2, Pt 8, Ch 1, 15.2 Safety valves 15.2.8* may be accepted as meeting these requirements where the arrangements comply with this paragraph.

15.2.11 Full particulars of the proposed arrangements are to be submitted for consideration.

15.2.12 Where the receiver is fitted with safety valves to relieve the steam output of the economiser and the economiser cannot be isolated from the receiver the requirements of *Vol 2, Pt 8, Ch 1, 15.2 Safety valves 15.2.9* may be waived.

15.2.13 The designed discharge capacities of the safety valves on each boiler and steam generator are to be found from the following formulae:

(a) Saturated steam safety valves:

$$E = \frac{AC(p + 1,03)}{98,1}$$

Superheated steam safety valves:

$$E = \frac{AC(p + 1,03)}{98,1}\sqrt{\frac{V_{\mathrm{s}}}{V_{\mathrm{H}}}}$$

where

p = set pressure, in bar gauge

A = for ordinary, high lift or improved high lift safety valves, the aggregate area, in mm^2, of the orifices through the seatings of the valves, neglecting the area of guides and other obstructions

= for full lift safety valves, the net aggregate area, in mm^2, through the seats after deducting the area of the guides or other obstructions when the valves are fully lifted

C = 4,8 for valves of ordinary type having a minimum lift of $\frac{D}{24}$

= 7,2 for valves of high lift type, having a minimum lift of $\frac{D}{16}$

= 9,6 for valves of improved high lift type having a minimum lift of $\frac{D}{12}$

= 19,2 for valves of full lift type having a minimum lift of $\frac{D}{4}$

D = bore of valve seat, in mm

E = the maker's specified peak load evaporation, in kg/hour (including all evaporation from water walls, integral, or steaming economisers and other heating surfaces in direct communication with the boiler)

V_{H} = specific volume of superheated steam (m^3/kg)

V_{S} = specific volume of saturated steam (m^3/kg).

15.2.14 When the discharge capacity of a safety valve of approved design has been established by type tests, carried out in the presence of the Surveyors or by an independent authority recognised by LR, on valves representative of the range of sizes and pressures intended for marine application, consideration will be given to the use of a constant higher than C = 19,2, based on 90 per cent of the measured capacity up to a maximum of C = 45 for full lift safety valves.

15.2.15 Pressurised thermal liquid and pressurised hot water heaters are to be provided with a safety relief device. The safety valve is to be designed and constructed in accordance with a relevant National or International Standard acceptable to LR.

15.3 Waste steam pipes

15.3.1 For ordinary, high lift and improved high lift type valves, the cross-sectional area of the waste steam pipe and passages leading to it is to be at least 10 per cent greater than the aggregate area of the safety valves as used in the formulae in *Vol 2, Pt 8, Ch 1, 15.2 Safety valves 15.2.13*. For full lift and other approved valves of high discharge capacity, the cross-sectional area of the waste steam pipe and passages is to be not less than 0,1C times the aggregate valve area.

15.3.2 The cross-sectional area of the main waste steam pipe is to be not less than the combined cross-sectional areas of the branch waste steam pipes leading thereto from the boiler safety valves.

15.3.3 Waste steam pipes are to be led to the atmosphere and are to be adequately supported and provided with suitable expansion joints, bends or other means to relieve the safety valve chests of undue loading.

15.3.4 The scantlings of waste steam pipes and silencers are to be suitable for the maximum pressure to which the pipes may be subjected in service, and in any case not less than 10 bar.

15.3.5 Silencers fitted to waste steam pipes are to be so designed that the clear area through the baffle plates is not less than that required for the pipes.

15.3.6 The safety valves of each exhaust gas heated economiser and exhaust gas heated boiler which may be used as an economiser are to be provided with entirely separate waste steam pipes.

15.3.7 External drains and exhaust steam vents to atmosphere are not to be led to waste steam pipes.

15.3.8 It is recommended that a scale trap and means for cleaning be provided at the base of each waste steam pipe.

15.4 Adjustment and accumulation tests

15.4.1 All safety valves are to be set under steam to a pressure not greater than the approved pressure of the boiler. As a working tolerance the setting is acceptable provided the valves lift at not more than 103 per cent of the approved design pressure. During a test of 15 minutes with the stop valves closed and under full firing conditions the accumulation of pressure is not to

exceed 10 per cent of the design pressure. During this test no more feed water is to be supplied than is necessary to maintain a safe working water level.

15.5 Stop valves

15.5.1 One main stop valve is to be fitted to each boiler and secured directly to the shell. There are to be as few auxiliary stop valves as possible so as to avoid piercing the boiler shell more than is absolutely necessary.

15.5.2 Where two or more boilers are connected together:

- Stop valves of self-closing or non-return type are to be fitted.
- Mobility and/or Ship Type systems are to be capable of being supplied from at least two boilers.

15.6 Water level indicators

15.6.1 Every boiler designed to contain water at a specified level is to be fitted with at least two means for indicating its water level, at least one of which is to be a direct reading gauge glass. The other means is to be either an additional gauge glass or an approved equivalent device. The required water level indicators are to be independent of each other.

15.6.2 Where a pair of gauge glasses are set at different levels to provide an extended range of water level indication they will only be considered as one water level indicator.

15.6.3 An approved equivalent device for level indication may derive its level input signal from one of the low water level detection systems required by *Vol 2, Pt 8, Ch 1, 15.7 Low water level fuel shut-off and alarm 15.7.1* provided that in the event of a power supply failure to that system an alarm is initiated and the fuel oil supply to the burners, or any other fuel used to fire the boiler, is automatically shut-off. The fuel supply shut-off will only be required if the power supply failure results in the direct reading gauge glass being the only functioning water level indicator.

15.6.4 The water gauges are to be readily accessible and placed so that the water level is clearly visible. The lowest visible parts of water gauges, are to be situated at the lowest safe working level.

15.6.5 The level of the highest part of the effective heating surfaces, e.g. combustion chamber top of a horizontal boiler and the furnace crown of a vertical boiler, is to be clearly marked in a position adjacent to the glass water gauge.

15.6.6 The cocks of all water gauges are to be operable from positions free from danger in the event of the glass breaking.

15.7 Low water level fuel shut-off and alarm

15.7.1 Every fired boiler designed to contain water at a specified level is to be fitted with two systems of water level detection which are to be independent of each other, and which will operate an alarm and shut-off automatically the fuel supply to the burners, or any other fuel used to fire the boiler, when the water level falls to a predetermined low level. These level detectors, in addition, may be used for other functions, e.g. high level alarm, feed pump control, etc.

15.8 Feed check valves

15.8.1 Two feed check and stop valves, connected to separate feed lines, are to be provided for all main and auxiliary boilers which are required for Mobility and/or Ship Type systems. The feed check and stop valves may be connected to a single standpipe at the shell. In the case of steam/steam generators one feed check valve is acceptable provided steam for Mobility and Ship Type systems is simultaneously available from another source.

15.9 Pressure gauges

15.9.1 Each boiler is to be provided with a separate steam pressure gauge.

15.9.2 The gauges are to be placed where they are easily read.

15.10 Blow-down and scum valves

15.10.1 Each boiler is to be fitted with at least one blowdown valve.

15.10.2 The blow-down valve is to be attached, wherever practicable, direct to the lower part of the boiler. Where it is not practicable to attach the blow-down valve directly, a steel pipe supported from the boiler may be fitted between the boiler and valve.

15.10.3 The blow-down valve and its connections to the sea need not be more than 38 mm, and is to be not less than 19 mm internal diameter. For cylindrical boilers the size of the valve may be generally 0,0085 times the diameter of the boiler.

15.10.4 Blow-down valves and scum valves (where the latter are fitted) of two or more boilers may be connected to one common discharge, but where thus arranged there are to be screw-down non-return valves fitted for each boiler to prevent the possibility of the contents of one boiler passing to another.

15.10.5 For blow-down valves or cocks on the ship's side and attachments, *see Vol 2, Pt 7, Ch 2, 2 Construction and installation*

15.11 Sampling valve or cock

15.11.1 Each boiler is to be provided with a sampling valve or cock secured direct to the boiler in a convenient position. The valve or cock is not to be on the water gauge standpipe.

15.12 Additional requirements for shell type exhaust gas steaming economisers

15.12.1 The design and construction of shell type economisers are to pay particular attention to the welding, heat treatment and inspection arrangements at the tube plate connection to the shell.

15.12.2 Every shell type economiser is to be provided with removable lagging at the circumference of the tube end plates to enable ultrasonic examination of the tube plate to shell connection.

15.12.3 Every economiser is to be provided with arrangements for pre-heating and de-aeration, and addition of water treatment or combination thereof, to control the quality of feed water to within the manufacturer's recommendations.

15.12.4 The manufacturer is to provide operating instructions for each economiser which is to include reference to:

- Feed water treatment and sampling arrangements.
- Operating temperatures-exhaust gas and feed water temperatures.
- Operating pressure.
- Inspection and cleaning procedures.
- Records of maintenance and inspection.
- The need to maintain adequate water flow through the economiser under all operating conditions.
- Periodical operational checks of the safety devices to be carried out by the operating personnel and to be documented accordingly.
- Procedures for using the exhaust gas economiser in the dry condition.
- Procedures for maintenance and overhaul of safety valves.
- Emergency operating procedures.

■ *Section 16*
Mountings and fittings for water tube boilers

16.1 General

16.1.1 Mountings and fittings not mentioned in this Section are to be in accordance with the requirements in *Vol 2, Pt 8, Ch 1, 15 Mountings and fittings for cylindrical and vertical boilers, steam generators, pressurised thermal liquid and pressurised hot water heaters*

16.2 Safety valves

16.2.1 Water tube boilers are to be fitted with not less than two safety valves of area and design in general accordance with the requirements of *Vol 2, Pt 8, Ch 1, 15.2 Safety valves*

16.2.2 Each saturated steam drum and each superheater are to be provided with at least one safety valve.

16.2.3 Where the superheater forms an integral part of the boiler, the relieving capacity of the superheater safety valve(s), based on the reduced pressure at the superheater outlet, may be included as part of the total relieving capacity required for the boiler. As some Naval Administrations may limit the proportion of the superheater safety valve relieving capacity which may be credited towards the total capacity for the boiler, Builders should give attention to any relevant requirements of the Naval Administration as specified.

16.2.4 The boiler and superheater valves are to be so disposed and proportioned between saturated steam drum and superheater outlet that the superheater will be protected from overheating under all service conditions, including an emergency stop of the ship at full power.

16.2.5 Where it is proposed to fit full bore safety valves operated by independent pilot valves, the arrangements are to be submitted for consideration. The pipes connecting pilot valves and main valves are to be of ample bore and wall thickness to minimise the possibility of obstruction and damage.

16.2.6 Where it is impracticable to attach safety valves directly to the superheater, the valves are to be located as near as possible thereto and fitted to a branch piece connected to the superheater outlet pipe.

16.2.7 In high temperature installations the drains from safety valves are to be led to a tank or other place where high temperature steam can be safely discharged.

16.3 Safety valve settings

16.3.1 All boiler and superheater safety valves are to be set under steam to their respective working pressures, which are not to be greater than the approved design pressure of the boiler. As a working tolerance the setting is acceptable provided the valves lift at not more than 103 per cent of the approved pressure.

16.3.2 In the setting of superheater safety valves, allowance is to be made for the pressure drop through the superheater so that under discharge conditions the pressure in the boiler will not exceed the approved boiler pressure.

16.3.3 In no case is the superheater safety valve setting to exceed by more than three per cent the pressure for which the steam piping is approved.

16.4 Waste steam pipes

16.4.1 The waste steam pipe and passages leading to it from the safety valves are to be in general accordance with the requirements of 15.3.

16.4.2 In installations operating with a high degree of superheat, consideration is to be given to the high temperatures which waste steam pipes, silencers and surrounding spaces will attain when the superheater safety valves are blowing during accumulation tests and in service, adequate protection against heat effects is to be provided to the Surveyor’s satisfaction.

16.4.3 Waste steam pipes are to be led well clear of electric cables and any parts or structures sensitive to heat or likely to distort; the pipes are to be insulated where necessary. In these installations each boiler should have a separate waste steam pipe system to atmosphere, with supporting and expansion arrangements such that no direct loading is imposed on the safety valve chests.

16.5 Accumulation tests

16.5.1 Tests for accumulation of pressure are to be carried out with the stop valve closed and under full firing conditions for a period not exceeding seven minutes. The accumulation is not to exceed 10 per cent of the design pressure.

16.5.2 Where accumulation tests might endanger the superheaters, consideration will be given in cases of fired boilers to the omission of these tests, provided that application is made when the boiler plan and sizes of safety valves are submitted for approval, and that the safety valves are of an approved type for which the capacity has been established by test in the presence of the Surveyors or an approved independent authority, or for which LR is satisfied, by long experience of accumulation tests, that the capacity is adequate. When it is agreed to waive accumulation tests, it will be required that the valve makers provide a certificate for each safety valve, stating its rated capacity at the approved working conditions of the boilers and that the boiler makers provide a certificate for each boiler stating its maximum evaporation.

16.5.3 The safety valves are to be found satisfactory in operation under working conditions during the trials of the machinery on board ship.

16.6 Water level indicators

16.6.1 Every boiler designed to contain water at a specified level is to be fitted with at least two means for indicating its water level, at least one of which is to be a direct reading gauge glass. The other means is to be either an additional gauge glass or an approved equivalent device. The required water level indicators are to be independent of each other.

16.6.2 Where a pair of gauge glasses are set at different levels to provide an extended range of water level indication they will only be considered as one water level indicator.

16.6.3 An approved equivalent device for level indication may derive its level input signal from one of the low water level detection systems required by *Vol 2, Pt 8, Ch 1, 16.7 Low water level fuel shut-off and alarm 16.7.1* provided that in the event of a power supply failure to that system an alarm is initiated and the fuel oil supply to the burners, or any other fuel used to fire the boiler, is automatically shut-off. The fuel supply shut-off will only be required if the power supply failure results in the direct reading gauge glass being the only functioning water level indicator.

16.6.4 Where a steam and water drum exceeding 4 m in length is fitted athwartships, two glass water gauges are to be fitted in suitable positions, one near each end of the drum.

16.6.5 The position of the glass water gauge of boilers in which the tubes are entirely drowned when cold is to be such that water is just showing in the glass when the water level in the steam drum is just above the top of the uppermost tubes when the boiler is cold.

16.6.6 In boilers, the tubes of which are not entirely drowned when cold, the glass water gauges are to be placed, to the Surveyor's satisfaction, in the positions which have been found by experience to indicate satisfactorily that the water content is sufficient for safety when the boiler is worked under all service conditions.

16.7 Low water level fuel shut-off and alarm

16.7.1 Every fired boiler designed to contain water at a specified level is to be fitted with two systems of water level detection which are to be independent of each other, and which will operate an alarm and shut-off automatically the fuel supply to the burners when the water level falls to a predetermined low level. These level detectors may be used for other functions, e.g. high level alarm, feed pump control, etc.

16.7.2 Any proposals to depart from these requirements in the case of small auxiliary boilers will be the subject of special consideration.

16.8 Feed check valves and water level regulators

16.8.1 Two feed check and stop valves, connected to separate feed lines, are to be provided for each boiler and are to be attached, wherever practicable, direct to the boiler or to an economiser which forms an integral part of the boiler.

16.8.2 Where the arrangements necessitate the use of a common inlet pipe on the economiser for both main and auxiliary feed systems, this pipe is to be as short as practicable, and the arrangements of check valves is to be such that either feed line can be effectively isolated without interruption of the feed water supply to the boiler.

16.8.3 At least one of the feed water systems is to be fitted with an approved feed water regulator whereby the water level in the boilers is controlled automatically. *See Vol 2, Pt 7, Ch 3, 6 Boiler feed water, condensate and thermal fluid circulation systems* for arrangements and details of boiler feed systems.

16.8.4 The feed check valves are to be fitted with efficient gearing, whereby they can be satisfactorily worked from the stokehold floor, or other convenient position.

16.8.5 Standpipes on boilers, for feed inlets, are to be designed with an internal pipe to prevent direct contact between the feed pipe and the boiler shell or end plates with the object of minimising thermal stresses in these plates. Similar arrangements are to be provided for desuperheater and other connections where significant temperature differences occur in service.

■ *Section 17* Hydraulic tests

17.1 General

17.1.1 Boilers and pressure vessels, together with their components are to withstand the following hydraulic tests without any sign of weakness or defect.

17.1.2 Having regard to the variation in the types and design of boilers, the hydraulic test may be carried out by either of the methods indicated below:

(a) boilers are to be tested on completion to a pressure 1,5 times the approved design pressure, or
(b) where construction permits, all components of the boiler are to be tested on completion of the work including heat treatment to 1,5 times the design pressure. In the case of components such as drums or headers, which are to be drilled for tube

holes, the test may be before drilling the tube holes, but is to be after the attachment of standpipes, stubs and similar fittings and also after heat treatment has been carried out. Where all the components have been tested as above, each completed boiler after assembly is to be tested to 1,25 times the design pressure.

17.2 Mountings

17.2.1 All boiler mountings are to be subjected to a hydraulic test of twice the approved design pressure with the exception of feed check valves and other mountings connected to the main feed system which are to be tested to 2,5 times the approved boiler design pressure, or twice the maximum pressure which can be developed in the feed line in normal service, whichever is greater.

■ *Section 18* Control and monitoring

18.1 General

18.1.1 The Control and Monitoring systems are to comply with the requirements of *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*.

18.2 Automatic and remote controls

18.2.1 Where a boiler is fitted with automatic or remote controls so that under normal operating conditions it does not require normal intervention by the operators, it is to be provided with alarms and safety arrangements required by *Vol 2, Pt 8, Ch 1, 18.2 Automatic and remote controls 18.2.2* and *Table 1.18.1 Boilers: Alarms and safeguards*

18.2.2 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery is required by *Table 1.18.1 Boilers: Alarms and safeguards*, the sensors and circuits utilised for the second stage alarm and automatic shutdown are to be independent of those required for the first stage alarm.

18.2.3 The following boiler services are to be fitted with automatic controls so as to maintain steady state conditions throughout the normal operating range of the boiler:

(a) Combustion system.
(b) Fuel oil supply temperature or viscosity, fuel oil grades requiring heating or cooling, as applicable.
(c) Boiler drum water level.
(d) De-aerator water level where applicable.
(e) Superheated steam pressure where applicable.
(f) Superheated steam temperature where applicable.
(g) De-superheated steam pressure where applicable.
(h) De-superheated steam temperature where applicable.

18.2.4 Safety systems and overrides are to comply with the requirements of*Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding 2.4.8*.

18.2.5 Burner controls are to be arranged such that light off is only possible at the minimum firing rate compatible with flame establishment. If ignition is set to occur at a fuel rich condition the burner is to revert to the correct operating air/fuel ratio on establishment of a stable flame.

18.2.6 Where water level indicators are dependent upon an external power supply, the fuel oil supply to the burners is to be automatically shut off in the event of power or signal failure.

18.2.7 Burner fuel oil valve(s) are not to open:

- prior to completion of required warm up times; or
- when the power supply to the igniter has failed; or
- prior to the completion of furnace purging, *see Vol 2, Pt 7, Ch 3, 3.1 Oil burning units 3.1.9*.

18.2.8 Arrangements for flame failure detection are to be provided with self-monitoring capabilities which prove that the flame detector is not erroneously indicating the presence of a flame. In the event of failure being detected by these selfmonitoring capabilities:

- fuel oil to the burner is to be shut-off automatically;
and
- an alarm is to be activated.

18.2.9 Where established as necessary by*Vol 2, Pt 7, Ch 3, 3.1 Oil burning units 3.1.10* means are to be provided to prevent starting of the ignition sequence following multiple flame failures until completion of the identified lock out period.

18.2.10 Following burner shutdown, the furnace is to be purged automatically for at least the required pre-purging time. In event of shutdown due to activation of a required safeguard this purging is to be manually initiated.

Table 1.18.1 Boilers: Alarms and safeguards

Item	Alarm	Note
Water level*	Low	Two water level sensors are to be provided each to operate independently, and automatically shut off the fuel oil to the burners and operate alarms. *See* Notes 1 to 3, and Note 5
	1st stage high*	
Water level	2nd stage high	Where applicable; automatic closure of turbine steam inlet valves. *See Vol 2, Pt 8, Ch 1, 18.2 Automatic and remote controls 18.2.2*
Steam drum or superheater outlet pressure	High and low	—
Superheated steam temperature	High	—
De-superheated steam temperature*	High	—
Feed water forced circulation flow (if fitted)	Low	Fuel oil to burners to be shut off automatically, *see* Note 5
Feed water pH	Low	When automatic dosing of feed water fitted
Feed water salinity	High	Fitted in boiler feed system
Feed water temperature	Low	When automatic temperature control fitted
Combustion air pressure*	Low	Fuel oil to burners to be shut off automatically, *see* Note 5
Fuel oil pressure*	Low	—
Fuel oil temperature or viscosity*	High and low	Heavy oil only
Fuel oil atomising steam/air pressure	Low	—
Burner flame and ignition*	Failure	Each burner to be monitored. Fuel oil to burner(s) to be shut off automatically, *see Vol 2, Pt 7, Ch 3, 3.1 Oil burning units 3.1.11*and *Vol 2, Pt 7, Ch 3, 3.1 Oil burning units 3.1.12*, and Note 5
Flame monitoring device(s)*	Failure	*See Vol 2, Pt 8, Ch 1, 18.2 Automatic and remote controls 18.2.8*and Note 5
Igniter*	Failure	Each igniter to be checked before oil is supplied to burner(s), *see* Note 5
Forced draft fan*	Power Failure	Fuel oil burners to be shut off automatically, *see* Note 5
Air register and dampers (including those in the uptake)*	Not fully open	Purge sequences to be inhibited, *see Vol 2, Pt 7, Ch 3, 3.1 Oil burning units 3.1.9*

Control system*	Power Failure	Fuel oil to burners to be shut-off automatically. Control using alternative arrangements is to remain available, *see Vol 2, Pt 9, Ch 7, 4.5 Control systems, general requirements 4.5.7*.
Feed water or water forced circulation flow (if fitted)	Low	Fuel oil to burners to be shut off automatically, *see* Notes 5 and 6
Uptake temperature	High	Where economiser and/or gas air heaters are integral with the boiler and also for independent exhaust gas boilers/ economisers, to monitor for soot fires. *See* Note 7

Note 1. For dual evaporation boilers the primary circuit is to be fitted with two independent low water level detectors which will operate alarms and shut off the fuel to the burners automatically. The secondary circuit is to be fitted with one low water level detector which will operate alarms and shut off the fuel oil to the burners automatically. Additionally one high water level alarm is to be fitted on the secondary circuit which may be operated by the same detector as that provided for low water level detection.

Note 2. Only one independent system of low water level detection, alarm and automatic fuel shut-off need be fitted in the case of small forced circulation or re-circulation coiled water tube 'package' type boilers when evaporation is less than 2900 kg/hr or the heating surface is less than $100 m^2$.

Note 3. Where two level sensors are provided these may be used for other functions, e.g. high level alarm, level control, trip systems, etc.

Note 4. For boilers not supplying steam for propulsion or for services essential for the safety or operation of the ship at sea, only the items marked * are required.

Note 5. These safeguards are to remain operative during automatic, manual and emergency operation.

Note 6. For exhaust gas economisers/boilers requiring feed water or forced water circulation, the low flow alarm is to be fitted with provision to override the alarm if the exhaust gas economiser/boiler is to be operated in the dry condition. *See also Vol 2, Pt 7, Ch 3, 6.2 Feed and circulation pumps 6.2.4*.

Note 7. Alternatively, details (including location) of an appropriate fire detection system are to be submitted for consideration.

■ *Section 1* General requirements

1.1 Application

1.1.1 The requirements of this Chapter are applicable to fusion welded pressure vessels and plate heat exchangers, intended for marine purposes but not included in *Vol 2, Pt 8, Ch 1 Steam Raising Plant and Associated Pressure Vessels*. The equations in this Chapter may be used for determining the thickness of seamless pressure vessels using a joint factor of 1,0. Seamless pressure vessels are to be manufactured and tested in accordance with the requirements of *Ch 5 Steel Forgings* of the *Rules for the Manufacture, Testing and Certification of Materials, July 2015* (hereinafter referred to as the Rules for Materials).

1.1.2 Where the required design criteria for pressure vessels are not indicated within this Chapter, the relevant Sections of *Vol 2, Pt 8, Ch 1 Steam Raising Plant and Associated Pressure Vessels* are applicable.

1.2 Definition of symbols

1.2.1 The symbols used in the various formulae in Sections *Vol 2, Pt 8, Ch 2, 2 Cylindrical shells and drums subject to internal pressure*, unless otherwise stated, are defined as follows, and are applicable to the specific part of the pressure vessel under consideration:

d = diameter of hole, or opening, in mm

p = design pressure, *see Vol 2, Pt 8, Ch 2, 1.3 Design pressure*, in bar

r_i = inside knuckle radius, in mm

r_o = outside knuckle radius, in mm

s = pitch, in mm

t = minimum thickness, in mm

D_i = inside diameter, in mm

D_o = outside diameter, in mm

J = joint factor applicable to welded seams, *see Vol 2, Pt 8, Ch 2, 1.9 Joint factors*, or ligament efficiency between tube holes (expressed as a fraction, *see Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes*)

R_i = inside radius, in mm

R_o = outside radius, in mm

T = design temperature, in °C.

σ = allowable stress, *see Vol 2, Pt 8, Ch 2, 1.8 Allowable stress*, in N/mm^2

1.2.2 Where reference is made to calculated or actual plate thickness for the derivation of other values, these thicknesses are to be minus the standard Rule corrosion allowance of 0,75 mm, if not so stated.

1.3 Design pressure

1.3.1 The design pressure is the maximum permissible working pressure, and is to be not less than the highest set pressure of any relief valve.

1.3.2 Calculations made to determine the scantlings of the pressure parts are to be based on the design pressure, adjusted where necessary to take account of pressure variations corresponding to the most severe operational conditions.

1.3.3 It is desirable that there should be a margin between the normal pressure at which the pressure vessel operates and the lowest pressure at which any relief valve is set to lift, to prevent unnecessary lifting of the relief valve.

1.4 Metal temperature

1.4.1 The metal temperature, T, used to evaluate the allowable stress, s, is to be taken as the actual metal temperature expected under operating conditions for the pressure part concerned, and is to be stated by the manufacturer when plans of the pressure parts are submitted for consideration.

1.4.2 The design temperature, T, for calculation purposes is to be not less than 50ºC.

1.5 Classification of fusion welded pressure vessels

1.5.1 For Rule purposes, pressure vessels are graded as Class 1 where the shell thickness exceeds 38 mm.

1.5.2 For Rule purposes, pressure vessels are graded as Class 2/1 and Class 2/2 if they comply with the following conditions:

(a) where the design pressure exceeds 17,2 bar; or
(b) where the metal temperature exceeds 150°C; or
(c) where the design pressure, in bar, multiplied by the actual thickness of the shell, in mm, exceeds 157; or
(d) where the shell thickness does not exceed 38 mm.

1.5.3 For Rule purposes, Class 3 pressure vessels are to have a maximum shell thickness of 16 mm, and are pressure vessels not included in Classes 1, 2/1 or 2/2.

1.5.4 Pressure vessels which are constructed in accordance with Classes 2/1, 2/2 or 3 standards (as indicated above) will, if manufactured in accordance with the requirements of superior Class, be approved with the scantlings appropriate to that Class.

1.5.5 Pressure vessels which only have circumferential fusion welded seams, will be considered as seamless with no Class being assigned. Preliminary weld procedure tests and non-destructive examination for the circumferential seam welds should be carried out for the equivalent Class as determined by *Vol 2, Pt 8, Ch 2, 1.5 Classification of fusion welded pressure vessels 1.5.1*, *Vol 2, Pt 8, Ch 2, 1.5 Classification of fusion welded pressure vessels 1.5.2* and *Vol 2, Pt 8, Ch 2, 1.5 Classification of fusion welded pressure vessels 1.5.3*

1.5.6 In special circumstances relating to service conditions, materials, operating temperature, the carriage of dangerous gases and liquids, etc. it may be required that certain pressure vessels be manufactured in accordance with the requirements of a superior Class.

1.5.7 Details of heat treatment, non-destructive examination and routine tests (where required) are given in *Ch 13 Requirements for Welded Construction* of the Rules for Materials.

1.5.8 Hydraulic testing is required for all classes of pressure vessels.

1.5.9 For a full definition of Classes of pressure vessels relating to boilers and associated pressure vessels, *see Vol 2, Pt 8, Ch 1, 1 General requirements*.

1.6 Plans

1.6.1 Plans of pressure vessels are to be submitted in triplicate for consideration where all the conditions in (a) or (b) are satisfied:

(a) The vessel contains vapours or gases, e.g. air receivers, hydrophore or similar vessels and gaseous CO_2 vessels for fire-fighting, and

$p_V > 600$

$p > 1$

$V > 100$

V = volume (litres) of gas or vapour space

(b) The vessel contains liquefied gases, or flammable liquids

$p > 7$

$V > 100$

V = volume (litres)

p is as defined in *Vol 2, Pt 8, Ch 2, 1.2 Definition of symbols 1.2.1*

1.6.2 Plans of full constructional features of the vessel and dimensional details of the weld preparations for longitudinal and circumferential seams and attachments, together with particulars of the welding consumables and of the mechanical properties of the materials, are to be submitted before construction is commenced.

1.7 Materials

1.7.1 Materials used in the construction of Class 1, 2/1 and 2/2 pressure vessels are to be manufactured, tested and certified in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials, July 2015*. Materials used in the construction of Class 3 pressure vessels may be in accordance with the requirements of an acceptable national or international specification. The manufacturer's certificate will be accepted in lieu of Lloyd's Register's (hereinafter referred to as 'LR') material certificate for such materials.*Rules for the Manufacture, Testing and Certification of Materials, July 2015*

1.7.2 The specified minimum tensile strength of carbon and carbon-manganese steel plates, pipes, forgings and castings is to be within the general limits of 340 to 520 N/mm^2.

1.7.3 The specified minimum tensile strength of low alloy steel plates, pipes, forgings and castings is to be within the general limits of 400 to 500 N/mm^2, and pressure vessels made in these steels are to be either seamless or Class 1 fusion welded.

1.7.4 Where it is proposed to use materials other than those specified in the *Rules for the Manufacture, Testing and Certification of Materials, July 2015*, details of the chemical compositions, heat treatment and mechanical properties are to be submitted for approval. In such cases, the values of the mechanical properties used for deriving the allowable stress are to be subject to agreement by LR.

1.8 Allowable stress

1.8.1 The term 'allowable stress', σ, is the stress to be used in the formulae for the calculation of scantlings of pressure parts.

1.8.2 The allowable stress, s, is to be the lowest of the following values:

$$\sigma = \frac{E_t}{1,5} \quad \sigma = \frac{R_{20}}{2,7} \quad \sigma = \frac{S_R}{1,5}$$

where

E_t = specified minimum lower yield stress or 0,2 per cent proof stress at temperature, T for carbon and carbon-manganese steels. In the case of austenitic steels, the 1,0 per cent proof stress at temperature, T, is to be used

R_{20} = specified minimum tensile strength at room temperature

S_R = average stress to produce rupture in 100 000 hours at temperature, T

T = metal temperature, *see Vol 2, Pt 8, Ch 2, 1.4 Metal temperature*

1.8.3 The allowable stress for steel castings is to be taken as 80 per cent of the value determined by the method indicated in *Vol 2, Pt 8, Ch 2, 1.8 Allowable stress 1.8.2* using the appropriate values for cast steel.

1.8.4 Where steel castings, which have been tested in accordance with the *Rules for the Manufacture, Testing and Certification of Materials, July 2015*, are also subjected to nondestructive tests, consideration will be given to increasing the allowable stress using a factor up to 90 per cent in lieu of the 80 per cent referred to in *Vol 2, Pt 8, Ch 2, 1.8 Allowable stress 1.8.3*. Particulars of the nondestructive test proposals are to be submitted for consideration.

1.9 Joint factors

1.9.1 The following joint factors are to be used in the equations in *Vol 2, Pt 8, Ch 2, 2 Cylindrical shells and drums subject to internal pressure*, where applicable. Fusion welded pressure parts are to be made in accordance with *Vol 2, Pt 1, Ch 4 Requirements for Fusion Welding of Pressure Vessels and Piping*

Class of pressure vessel	Joint factor
Class 1	1,0
Class 2/1	0,85
Class 2/2	0,75
Class 3	0,60

1.9.2 The longitudinal joints for all Classes of vessels are to be butt joints. Circumferential joints for Class 1 vessels are also to be butt welds. Circumferential joints for Classes 2/1, 2/2 and 3 vessels should also be butt joints with the following exceptions:

(a) Circumferential joints for Classes 2/1, 2/2 and 3 vessels may be of the joggle type provided neither plate at the joints exceeds 16 mm thickness.
(b) Circumferential joints for Class 3 vessels may be of the lap type provided neither plate at the joint exceeds 16 mm thickness nor the internal diameter of the vessel exceeds 610 mm.

For typical acceptable methods of attaching flat ends, *see Figure 1.8.2 Toroidal furnace headers* and *Figure 1.9.1 Typical attachment of unflanged flat end plates to shell* .

For typical acceptable methods of attaching dished ends, *see Figure 2.8.1 Typical attachment of dished ends to cylindrical shell*

1.9.3 Where a pressure vessel is to be made of alloy steel, particulars of the welding consumables to be used, including typical mechanical properties and chemical composition of the deposited weld metal, are to be submitted for approval.

1.10 Pressure parts of irregular shape

1.10.1 Where pressure parts are of such irregular shape that it is impracticable to design their scantlings by the application of the formulae in *Vol 2, Pt 8, Ch 2, 2 Cylindrical shells and drums subject to internal pressure*, the suitability of their construction is to be determined by hydraulic proof test of a prototype or by an agreed alternative method.

1.11 Adverse working conditions

1.11.1 Where working conditions are adverse, special consideration may require to be given to increasing the scantlings derived from the formulae. In this connection, where necessary, account should also be taken of any excess of loading resulting from:

(a) impact loads, including rapidly fluctuating pressures,
(b) weight of the vessel and normal contents under operating and test conditions,
(c) superimposed loads, such as other pressure vessels, operating equipment, insulation, corrosion-resistant or erosion-resistant linings and piping,
(d) reactions of supporting lugs, rings, saddles or other types of supports, or
(e) the effect of temperature gradients on maximum stress.

Section 2
Cylindrical shells and drums subject to internal pressure

2.1 Minimum thickness

2.1.1 The minimum thickness, *t*, of a cylindrical shell is to be determined by the following formula:

$$t = \frac{pR_\mathrm{i}}{10\,\sigma\,J - 0,5p} + 0,75\ \mathrm{mm}$$

where

t, p, R_i and σ are as defined in *Vol 2, Pt 8, Ch 2, 1.2 Definition of symbols*

J = the joint factor of the longitudinal joints (expressed as a fraction). *See Vol 2, Pt 8, Ch 2, 1.9 Joint factors* in the case of seamless shells clear of openings *J* = 1,0.

2.1.2 The formula in *Vol 2, Pt 8, Ch 2, 2.1 Minimum thickness 2.1.1* is applicable only where the resulting thickness does not exceed half the internal radius, i.e. where R_o is not greater than 1,5R_i.

2.1.3 Irrespective of the thickness determined by the formula in *Vol 2, Pt 8, Ch 2, 2.1 Minimum thickness 2.1.1*, *t* is to be not less than $3 + \frac{D_\mathrm{i}}{1500}$ mm, where D_i is as defined in *Vol 2, Pt 8, Ch 2, 1.2 Definition of symbols*. The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

2.2

2.2.1 For efficiency of ligaments between tube holes, *see Vol 2, Pt 8, Ch 1, 2.2 Efficiency of ligaments between tube holes*.

For compensating effect of tube stubs, *see Vol 2, Pt 8, Ch 1, 2.3 Compensating effect of tube stubs*

For unreinforced openings, *see Vol 2, Pt 8, Ch 1, 2.4 Unreinforced openings*

For reinforced openings, *see Vol 2, Pt 8, Ch 1, 2.5 Reinforced openings*

Section 3
Spherical shells subject to internal pressure

3.1 Minimum thickness

3.1.1 The minimum thickness, *t*, of a spherical shell is to be determined by the following formula:

$$t = \frac{pR_\mathrm{i}}{20\,\sigma\,J + 0,5p} + 0,75\ \mathrm{mm}$$

where *t*, *p*, R_i, σ and *J* are as defined in *Vol 2, Pt 8, Ch 2, 1.2 Definition of symbols*

3.1.2 The formula in *Vol 2, Pt 8, Ch 2, 3.1 Minimum thickness 3.1.1* is applicable only where the resulting thickness does not exceed half the internal radius.

3.1.3 Irrespective of the thickness determined by the formula in *Vol 2, Pt 8, Ch 2, 3.1 Minimum thickness 3.1.1*, *t* is to be not less than 3 + $\frac{D_\mathrm{i}}{1500}$ mm, where D_i is as defined in *Vol 2, Pt 8, Ch 2, 1.2 Definition of symbols*. The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

3.1.4 Openings in spherical shells requiring compensation are to comply in general, with *Vol 2, Pt 8, Ch 1, 2.5 Reinforced openings* using the calculated actual thickness of the spherical shell as applicable.

■ *Section 4*
Dished ends subject to internal pressure

4.1 Minimum thickness

4.1.1 The thickness, *t*, of semi-ellipsoidal, and hemispherical unstayed ends, and the knuckle section of torispherical ends dished from plate, having pressure on the concave side and satisfying the conditions listed below, is to be determined by the following formula:

$$t = \frac{pD_o K}{20\,\sigma\,J} + 0,75 \text{ mm}$$

where *t*, *p*, D_o, σ and *J* are as defined in *Vol 2, Pt 8, Ch 2, 1.2 Definition of symbols*

K = a shape factor, *see Vol 2, Pt 8, Ch 1, 4.2 Shape factors for dished ends* and *Figure 1.4.1 Shape factor*

4.1.2 For semi-ellipsoidal ends:

(a) the external height, $H \geq 0{,}18D_o$

where

D_o = the external diameter of the parallel portion of the end, in mm.

4.1.3 For torispherical ends:

(a) the internal radius, $R_i \leq D_o$

the internal knuckle radius, $r_i \geq 0{,}1D_o$

the internal knuckle radius, $r_i \geq 3t$

the external height, $H \geq 0{,}18D_o$, and is determined as follows:

$$H = R_o - \sqrt{(R_o - 0,5D_o)(R_o + 0,5D_o - 2r_o)}$$

4.1.4 In addition to the formula in *Vol 2, Pt 8, Ch 2, 4.1 Minimum thickness 4.1.1* the thickness, *t*, of a torispherical head made from more than one plate, in the crown section, is to be not less than that determined by the following formula:

$$t = \frac{pR_i}{20\,\sigma\,J - 0,5p} + 0,75 \text{ mm}$$

where *t*, *p*, R_i, σ, and *J* are as defined in *Vol 2, Pt 8, Ch 2, 1.2 Definition of symbols*

4.1.5 The thickness required by *Vol 2, Pt 8, Ch 2, 4.1 Minimum thickness 4.1.1* for the knuckle section of a torispherical head is to extend past the common tangent point of the knuckle and crown radii into the crown section for a distance not less than $0,5\sqrt{R_i t}$ mm, before reducing to the crown thickness permitted by *Vol 2, Pt 8, Ch 2, 4.1 Minimum thickness 4.1.4* where *t* = the required thickness from *Vol 2, Pt 8, Ch 2, 4.1 Minimum thickness 4.1.1*

4.1.6 In all cases, *H* is to be measured from the commencement of curvature (shown in *Figure 1.4.2 Typical dished ends*).

4.1.7 The minimum thickness of the head, *t*, is in no case to be less than $3 + \frac{D_i}{1500}$ mm, where D_i is as defined in *Vol 2, Pt 8, Ch 2, 1.2 Definition of symbols*. The minimum thickness permitted for vessels manufactured in corrosion resistant steels will be the subject of special consideration.

4.1.8 For ends which are butt welded to the drum shell, *see Vol 2, Pt 8, Ch 2, 1.9 Joint factors*, the thickness of the edge of the flange for connection to the shell is to be not less than the thickness of an unpierced seamless or welded shell, whichever is applicable, of the same diameter and material and determined by *Vol 2, Pt 8, Ch 2, 2.1 Minimum thickness*

4.2

4.2.1 For shape factors dished ends, *see Vol 2, Pt 8, Ch 1, 4.2 Shape factors for dished ends*

For dished ends with unreinforced openings, *see Vol 2, Pt 8, Ch 1, 4.3 Dished ends with unreinforced openings*

For flanged openings in dished ends, *see Vol 2, Pt 8, Ch 1, 4.4 Flanged openings in dished ends*.

For location of unreinforced and flanged openings in dished ends, *see Vol 2, Pt 8, Ch 1, 4.5 Location of unreinforced and flanged openings in dished ends*.

For dished ends with reinforced openings, *see Vol 2, Pt 8, Ch 1, 4.6 Dished ends with reinforced openings*

■ *Section 5*
Dished ends for Class 3 pressure vessels

5.1 Minimum thickness

5.1.1 As an alternative to the formula in *Vol 2, Pt 8, Ch 2, 4.1 Minimum thickness 4.1.1*, for Class 3 vessels only, the minimum thickness, t, of a torispherical unstayed end dished from plate and having pressure on the concave or convex side is to be determined by the following formula:

$$t = \frac{p\,R_{\mathrm{i}}}{CS}$$

where t, p, and R_{i} are as defined in *Vol 2, Pt 8, Ch 2, 1.2 Definition of symbols*

C = 2,57 for ends concave to pressure

= 1,65 for ends convex to pressure

S = specified minimum tensile strength of plate, N/mm^2, which should be not less than 410 N/mm^2.

5.1.2 The inside radius of curvature, R_{i}, of the end plate is to be not greater than the external diameter of the cylinder which it is attached.

5.1.3 The inside knuckle radius, r_{i}, of the arc joining cylindrical flange to the spherical surface of the end is to be not less than four times the thickness of the end plate, and no case less than 65 mm.

5.1.4 Ends convex to pressure are not to be used for vessels exceeding 610 mm internal diameter.

5.1.5 Where the end is provided with a flanged manhole, the thickness of the end, in mm, determined by *Vol 2, Pt 8, Ch 2, 5.1 Minimum thickness 5.1.1*, is to be increased by 3 mm, and the total depth, H, of the manhole flange, measured from the outer surface of the plate on minor axis, is to be not less than:

$$H = \sqrt{t_1\,W}$$

where

t_1 = required thickness of the plate, in mm

H = depth of flange, in mm.

W = minor axis of the manhole, in mm

■ *Section 6*
Conical ends subject to internal pressure

6.1 General

6.1.1 Conical ends and conical reducing sections, as shown in *Figure 1.5.1 Conical ends and conical reducing sections*, are to be designed in accordance with the equations given in *Vol 2, Pt 8, Ch 2, 6.2 Minimum thickness*

6.1.2 Connections between cylindrical shell and conical sections and ends should preferably be by means of a knuckle transition radius. Typical permitted details are shown in *Figure 1.5.1 Conical ends and conical reducing sections*. Alternatively, conical sections and ends may be butt welded to cylinders without a knuckle radius when the change in angle of slope, ψ, between the two sections under consideration does not exceed 30°.

6.1.3 Conical ends may be constructed of several ring sections of decreasing thickness as determined by the corresponding decreasing diameter.

6.2 Minimum thickness

6.2.1 The minimum thickness, *t*, of the cylinder, knuckle and conical section at the junction and within the distance *L* from the junction is to be determined by the following formula:

$$t = \frac{pD_{\text{o}}K}{20\,\sigma\,J} + 0,75\ \text{mm}$$

where *t*, *p*, σ and *J* are as defined in *Vol 2, Pt 8, Ch 2, 1.2 Definition of symbols*

D_{o} = outside diameter, in mm of the conical section or end, *see Figure 1.5.1 Conical ends and conical reducing sections*.

K = a factor, taking into account the stress in the knuckle, *see Table 1.5.1 Values of K as a function of ψ and* r_i / D_o.

6.2.2 If the distance of a circumferential seam from the knuckle or junction is not less than *L*, then *J* is to be taken as 1,0; otherwise *J* is to be taken as the weld joint factor appropriate to the circumferential seam,

where

r_{i} = inside radius of transition knuckle, in mm, which is to be taken as 0,01D_{c} in the case of conical sections without knuckle transition

L = distance, in mm, from knuckle or junction within which meridional stresses determine the required thickness, *see Figure 1.5.1 Conical ends and conical reducing sections*.

= $0,5\sqrt{\dfrac{D_{\text{o}}t}{cos\ \psi}}$

ψ = difference between angle of slope of two adjoining conical sections, *see Figure 1.5.1 Conical ends and conical reducing sections*.

6.2.3 The minimum thickness, *t*, of those parts of conical sections not less than a distance *L* from the junction with a cylinder or other conical section, is to be determined by the following formula:

$$t = \frac{pD_{\text{c}}}{20\,\sigma\,J - p}\,\frac{1}{cos\ \alpha} + 0,75\ \text{mm}$$

where

D_{c} = inside diameter, in mm, of conical section or end at the position under consideration, *see Figure 1.5.1 Conical ends and conical reducing sections*.

$\alpha, \alpha_1, \alpha_2$ = angle of slope of conical section (at the point under consideration) to the vessel axis, *see Figure 1.5.1 Conical ends and conical reducing sections*.

6.2.4 The thickness of conical sections having an angle of inclination to the vessel axis of more than 75° is to be determined as for a flat plate.

Section 7
Standpipes and branches

7.1 Minimum thickness

7.1.1 The minimum wall thickness, *t*, of standpipes and branches is to be not less than the greater of the two values determined by the following formulae, making such additions as may be necessary on account of bending, static loads and vibrations:

$$t = \frac{pD_{\text{o}}}{20\,\sigma\ + p} + 0,75\ \text{mm}$$

$$t = 0,015 D_{\text{o}} + 3,2\ \text{mm}$$

where *t*, *p*, D_{o} and σ are defined in *Vol 2, Pt 8, Ch 2, 1.2 Definition of symbols*

If the second formula applies, the thickness need only be maintained for a length, *L*, from the outside surface of the vessel, but need not extend past the first connection, butt weld or flange, where:

$$L = 3,5\sqrt{D_{\text{o}} t}\ \text{mm.}$$

7.1.2 In no case need the wall thickness exceed the minimum shell thickness as required by *Vol 2, Pt 8, Ch 2, 2.1 Minimum thickness*, *Vol 2, Pt 8, Ch 2, 3.1 Minimum thickness* or *Vol 2, Pt 8, Ch 2, 4.1 Minimum thickness* as applicable.

Section 8
Construction

8.1 Access arrangements

8.1.1 Pressure vessels are to be so made that the internal surfaces may be examined. Wherever practicable, the openings for this purpose are to be sufficiently large for access and for cleaning the inner surfaces.

8.1.2 Manholes in cylindrical shells should preferably have their shorter axes arranged longitudinally.

8.1.3 Doors for manholes and sightholes are to be formed from steel plate or of other approved construction, and all jointing surfaces are to be machined.

8.1.4 Doors of the internal type are to be provided with spigots which have a clearance of not more than 1,5 mm all round, i.e. the axes of the opening are not to exceed those of the door by more than 3 mm. The width of the manhole gasket seat is not to be less than 16 mm.

8.1.5 Doors of the internal type for openings not larger than 230 x 180 mm need be fitted with only one stud, which may be forged integral with the door. Doors for openings larger than 230 mm x 180 mm are to be fitted with two studs or bolts. The strength of the attachment to the door is not to be less than the strength of the stud or bolt.

8.1.6 The crossbars or dogs for doors are to be of steel.

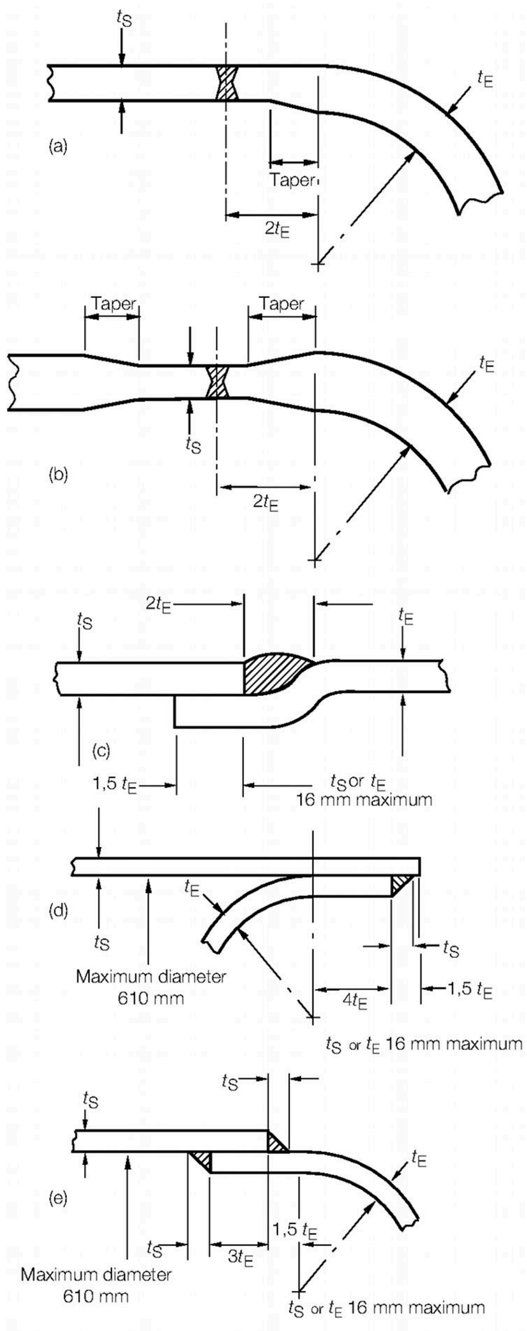
8.1.7 External circular flat cover plates are to be in accordance with a recognised standard.

8.2 Torispherical and semi-ellipsoidal ends

8.2.1 For typical acceptance types of attachment for dished ends to cylindrical shells, *see Figure 2.8.1 Typical attachment of dished ends to cylindrical shell* Types (d) and (e) are to be made a tight fit in the cylindrical shell.

8.2.2 Where the difference in thickness is the same throughout the circumference, the thicker plate is to be reduced in thickness by machining to a taper for a distance not less than four times the offset, so that the two plates are of equal thickness at the position of the circumferential weld. A parallel portion may be provided between the end of the taper and the weld edge preparation; alternatively, if so desired, the width of the weld may be included as part of the smooth taper of the thicker plate.

8.2.3 The thickness of the plates at the position of the circumferential weld is to be not less than that of an unpierced cylindrical shell of seamless or welded construction, whichever is applicable, of the same diameter and material, *see Vol 2, Pt 8, Ch 2, 2.1 Minimum thickness*



Type of end attachment	Acceptable for
(a) and (b)	All classes
(c)	2/1, 2/2 and 3
(d) and (e)	Class 3 only

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Figure 2.8.1 Typical attachment of dished ends to cylindrical shell

8.3

8.3.1 For hemispherical ends, *see Vol 2, Pt 8, Ch 1, 14.3 Hemispherical ends*

For openings in flat ends, *see Vol 2, Pt 8, Ch 1, 8.3 Toroidal furnace headers*For unstayed circular flat end plates, *see Vol 2, Pt 8, Ch 1, 8.3 Toroidal furnace headers*.

For welded-on flanges, butt joints and fabricated branch pieces, *see Vol 2, Pt 8, Ch 1, 14.4 Welded-on flanges, butt welded joints and fabricated branch pieces*.

For welded attachments to pressure vessels, *see Vol 2, Pt 8, Ch 1, 14.5 Welded attachments to pressure vessels*

■ *Section 9* Mountings and fittings

9.1 General

9.1.1 Each pressure vessel or system is to be fitted with a stop valve situated as close as possible to the shell.

9.1.2 Adequate arrangements are to be provided to prevent over-pressure of any part of a pressure vessel which can be isolated. Pressure gauges are to be fitted in positions where they can be easily read.

9.1.3 Adequate arrangements are to be provided for draining and venting the separate parts of each pressure vessel.

9.2 Receivers containing pressurised gases

9.2.1 Each air receiver is to be fitted with a drain arrangement at its lowest part, permitting oil and water to be blown out.

9.2.2 Each receiver which can be isolated from a relief valve is to be provided with a suitable fusible plug to discharge the contents in case of fire. The melting point of the fusible plug is to be approximately 150°C. *See also Vol 2, Pt 8, Ch 2, 9.2 Receivers containing pressurised gases 9.2.3* and *Vol 2, Pt 8, Ch 2, 9.2 Receivers containing pressurised gases 9.2.4*

9.2.3 Where a fixed system utilising fire-extinguishing gas is fitted, to protect a machinery space containing an air receiver(s), fitted with a fusible plug, it is recommended that the discharge from the fusible plug be piped to the open deck.

9.2.4 Receivers used for the storage of air for the control of remotely operated valves are to be fitted with relief valves and not fusible plugs.

9.3

9.3.1 For starting air pipe systems and safety fittings, *see Vol 2, Pt 8, Ch 2, 7 Standpipes and branches*.

■ *Section 10* Hydraulic tests

10.1 General

10.1.1 Pressure vessels covered by this Chapter are to be tested on completion to a pressure, p_{T}, determined by the following formula, without showing signs of weakness or defect:

$$p_{\mathrm{T}} = 1,3 \frac{\sigma_{50}}{\sigma_{\mathrm{T}}} \frac{t}{(t-0,75)} p$$

but in no case is to exceed

$$1,5 \frac{t}{(t-0,75)} p$$

where

p = design pressure, in bar

p_T = test pressure, in bar

t = nominal thickness of shell as indicated on the plan, in mm

σ_T = allowable stress at design temperature, in N/mm^2

σ_{50} = allowable stress at 50°C, in N/mm^2.

10.2 Mountings

10.2.1 Mountings are to be subjected to a hydraulic test of twice the approved design pressure.

■ *Section 11* Plate heat exchangers

11.1 General

11.1.1 Plate heat exchangers are to be classed as follows:

Class 2 where either of the following conditions apply:

(a) the maximum metal design temperature is 150°C or greater; or
(b) design pressure is 17,2 bar or greater.

Class 3 in all other cases.

11.1.2 Where the design temperature is equal to or lower than minus 10°C, a higher class is to apply.

General Requirements for the Design and Construction of Electrotechnical Systems

■ *Section 1* General requirements

1.1 Scope

1.1.1 The requirements of this Part apply to the design and construction philosophy of electrotechnical systems and equipment providing electrical power, control, alert or safety functions for the following:

- Main propulsion systems.
- Steering and manoeuvring systems.
- Electrical power systems.
- Mobility and ship type ancillary machinery systems.
- Engineering systems necessary for the watertight and weathertight integrity of the ship and functioning of ship type category systems.

1.1.2 Electrical services required to maintain the ship in a normal sea-going, operational and habitable condition are to be capable of being maintained without recourse to the emergency source of electrical power. The Mobility and/or Ship Type systems for individual types of ships for sea-going, operational and habitable conditions on board are to be agreed by Lloyd's Register (hereinafter referred to as 'LR'). *See also Vol 2, Pt 1, Ch 1, 3.1 Categories 3.1.5*, *Vol 2, Pt 1, Ch 1, 3.1 Categories 3.1.6* and *Vol 2, Pt 1, Ch 1, 3.1 Categories 3.1.7*

1.1.3 Electrotechnical services essential for safety are to be maintained under various emergency conditions.

1.1.4 The safety of crew and ship from electrical hazards is to be ensured.

1.2 Application

1.2.1 In addition to the requirements of this Chapter, *Vol 2, Pt 1, Ch 1 General Requirements for Classification of Engineering Systems*, Requirements for Classification of Engineering Systems and *Vol 2, Pt 1, Ch 2 Requirements for Machinery and Engineering Systems of Unconventional Design*, Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems shall be applied.

1.2.2 LR will be prepared to give consideration to special cases or to arrangements which are equivalent to the Rules where sufficient technical justification is provided.

1.2.3 Attention should also be given to any relevant requirements of the Naval Authority.

1.2.4 LR will be prepared to give consideration to cases where military arrangements require deviation from specific Rule requirements in this Chapter or where specialised naval standards, e.g. STANAG 1008 have been nominated and applied. Consideration will also be given to electrical arrangements of small ships and ships to be assigned class notation for restricted or special services.

1.2.5 Reference is to be made to *Vol 2, Pt 1, Ch 3, 4.9 Military requirements* concerning military requirements where these interface with the provisions of classification.

1.2.6 Assessment of performance parameters, such as accuracy, repeatability, etc. are to be in accordance with an acceptable specialised naval, standard, National or International Standard, e.g. IEC 60051, *Direct acting indicating analogue electrical measuring instruments and their accessories (all parts)*.

1.2.7 Equipment used in control, alarm and safety systems is to be suitable for its intended purpose, and accordingly, whenever practicable, be selected from the List of LR Type Approved Products published by LR.

1.2.8 Equipment shall be selected with due regard to its required strength and capability. System design is to ensure that, under normal operation and foreseeable abnormal conditions, the equipment's strength and capability is not exceeded in such a way as may give rise to danger or may affect other Mobility and/or Ship Type systems.

1.2.9 Special consideration will be given to arrangements that comply with a relevant and acceptable National or International Standard, such as IEC 60092-504: *Electrical installation on ships – Part 504: Special features – Control and instrumentation*.

1.3 Definitions

1.3.1 Reference is to be made to *Vol 2, Pt 1, Ch 1, 3 Engineering system designation* defining Mobility and Ship Type systems, services considered necessary for minimum comfortable conditions of habitability and services considered necessary to maintain the ship in a normal seagoing, operational and habitable condition.

1.3.2 An Emergency Stop (E-Stop) is a safeguard instigated by a single human action. It requires a stop of all movement within the controlled system as rapidly as possible to prevent a hazard occurring or to reduce an existing hazard to persons, machinery or the vessel.

1.3.3 An Emergency Trip (E-Trip) is a safeguard instigated by a single human action and means the disconnection of fuel, electrical, hydraulic or other power source from the controlled system to prevent a hazard occurring or to reduce an existing hazard to persons, machinery or the vessel. Movement within the system may be allowed to continue.

1.3.4 An Emergency Stop Function may be either an Emergency Stop or Emergency Trip, as appropriate to the system and risk being controlled.

1.3.5 A 'high voltage' is a voltage exceeding 1000 V a.c. or 1500 V d.c. between conductors, *see also Vol 2, Pt 9, Ch 3, 4.1 Systems of supply and distribution 4.1.4*.

1.3.6 A 'switchboard' is a switchgear and controlgear assembly for the control of power generated by a source of electrical power and its distribution to electrical consumers.

1.3.7 A 'section board' is a switchgear and controlgear assembly for controlling the supply of electrical power from a switchboard and distributing it to other section boards, distribution boards or final sub-circuits.

1.3.8 A 'distribution board' is an assembly of one or more protective devices arranged for the distribution of electrical power to final sub-circuits.

1.3.9 A 'final sub-circuit' is that portion of a wiring system extending beyond the final overcurrent device of a board.

1.3.10 'Special category spaces' are those enclosed spaces above or below the weather deck intended for the carriage of motor vehicles, helicopters and aircraft with fuel in their tanks, into and from which such equipment can be moved, and to which crew have access. Special category spaces may be accommodated on more than one deck provided that the total overall clear height for vehicles, helicopters and aircraft does not exceed 10 m.

1.3.11 'Machinery spaces of Category A' are those spaces and trunks to such spaces which contain:

(a) internal combustion machinery used for main propulsion; or
(b) internal combustion machinery used for purposes other than main propulsion where such machinery has in the aggregate a total power output of not less than 375 kW; or
(c) any oil-fired boiler or fuel oil unit.

1.3.12 'Dead ship condition' means that the entire machinery installation, including the power supply, is out of operation and that the auxiliary services for bringing the main propulsion systems into operation (e.g. compressed air, starting current from batteries, etc.) and for the restoration of the main power supply are not available. Means are to be made available to start the emergency generator at all times, *see Vol 2, Pt 2, Ch 1, 7.3 Starting of the emergency source of power*.

1.3.13 'Protected space' is a machinery space where a fixed water-based local application fire-fighting system is installed.

1.3.14 'Protected areas' are areas within a protected space which are protected by a fixed water-based local application fire-fighting system.

1.3.15 'Adjacent areas' are those, other than protected areas, exposed to direct spray or other areas where water may extend when a fixed water-based local application fire-fighting system is activated.

1.3.16 An ‘electric arc’ is an electrical discharge or a short-circuit through ionised air caused by isolation or insulation integrity failure.

1.3.17 ‘Incident energy’ is the amount of energy impressed on a surface, a certain distance from the source, generated during an electric arc event.

1.3.18 Alarm System: a system which will alert relevant personnel to faults, abnormal situations and other conditions requiring attention in the machinery and the safety and control systems.

1.3.19 Control System: a system which responds to input signals from the process and/or Operator and generates output signals causing the equipment under control to operate in the desired manner.

1.3.20 Failure: loss of the ability of a structure, system or element to function within acceptance criteria.

1.3.21 Fail safe: a system design such that, when a failure occurs, the system reverts to the least hazardous state.

1.3.22 A reasonably foreseeable abnormal condition is an event, incident or failure that:

- has happened and could happen again;
- is planned for (e.g. emergency actions cover such a situation, maintenance is undertaken to prevent it, etc.).

They should be identified by:

- using analysis processes that are capable of revealing abnormal conditions;
- employing a mix of personnel including competent safety/risk professionals and those with relevant domain knowledge and understanding to apply the processes;
- referencing relevant events and historic data; and documenting the results of the analysis.

1.3.23 Safety System: a designated system that:

- implements the required safety functions necessary to achieve or maintain a safe state for the equipment under control; and
- is intended to achieve, on its own or with other safety systems, the necessary safety needed for the required safety functions.

1.3.24 Safe State: state of equipment under control when safety is achieved. For some situations, a safe state only exists so long as the equipment under control is continuously controlled. Such continuous control may be for a short or indefinite period.

1.3.25 System: set of elements which interact according to a design, where an element of a system can be another system, called a sub-system, which may be a controlling system or a controlled system, and may include hardware, software and human interaction.

1.4 Documentation required for design review

1.4.1 The documentation in *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.2* is to be submitted for design review.

1.4.2 A description of operation (with explanatory diagrams), schematic diagrams of circuits, and lists of monitored parameters with relevant setpoints:

- Controllable pitch propellers.
- Electric generating plant.
- Incinerators.
- Miscellaneous machinery or equipment (where control, alarm and safety systems are specified in other Sections of the Rules).
- Fuel oil transfer and storage systems.
- Propulsion machinery and auxiliaries for Mobility and/or Ship Type Systems.
- Steam raising plant (boilers and their ancillary equipment).
- Steering systems.
- Thermal fluid heaters.
- Thrust units.
- Valve position indicating systems.
- Waste-heat systems.
- Water jets for propulsion purposes.

- Fixed water-based local application fire-fighting systems, *see Vol 2, Pt 9, Ch 9, 5.2 Fixed water-based local application fire-fighting systems*.

1.4.3 **System Operational Concept**. A description of how the control, alarm and safety systems for the main and auxiliary machinery and systems essential for the propulsion and safety of the ship provide effective means for operation and control during all ship operational conditions.

1.4.4 Single line diagram of main and emergency power and lighting systems which is to include:

(a) ratings of machines, transformers, batteries and semiconductor converters;
(b) all feeders connected to the main and emergency switchboards;
(c) section boards and distribution boards;
(d) insulation type, size and current loadings of cables; (normal operational and fault conditions);
(e) make, type and rating of circuit breakers and fuses;
(f) details of harmonic filters (where fitted).

1.4.5 A System Operational Concept of the electrical power system which details the capability and functionality under defined operating and emergency conditions is to be submitted, *see Vol 1, Pt 1, Ch 2, 2.2 Definitions*. The System Operational Concept is to be agreed between the designers and Owners and is to include:

(a) a description of operation of the main and emergency electrical power systems;
(b) an earthing philosophy document that defines the basic approach to be taken for earthing the electrical power systems and all electrical loads; and
(c) schedule of normal and emergency operating loads on the system estimated for the different operating conditions expected. The following details are to be provided to meet this requirement:
    (i) a description of the expected operating profiles (e.g. the number of generating sets connected when manoeuvring, at sea, etc.), including as required by *Pt 2, Ch 1,2.1.1*; and
    (ii) a schedule of the normal and emergency operating loads, which is to state the kilowatt rating of each load and a load factor between 0 and 1. The load factor is defined as the ratio of the calculated load to the maximum load possible over a declared duty cycle. As such, the load factor shall reflect:

- the duty cycle of the load; and
- the proportion of its maximum rating at which the load is expected to operate.

(d) the quality of power supplies required for each designated load, where this is required by *Vol 2, Pt 9, Ch 1, 2.1 Quality of power supplies (QPS) 2.1.3*.

1.4.6 Simplified diagrams of generator circuits, interconnector circuits and feeder circuits showing:

(a) protective devices, e.g. short circuit, overload, reverse power protection;
(b) instrumentation and synchronising devices;
(c) preference tripping;
(d) remote stops;
(e) earth fault indication/protection.

1.4.7 Calculations of short circuit currents at main and emergency switchboards and section boards including those fed from transformers, details of circuit-breaker and fuse operating times, settings and discrimination curves showing compliance with *Vol 2, Pt 9, Ch 4, 4.1 General* and *Vol 2, Pt 9, Ch 3, 8.6 Conductor size 8.6.2*.

1.4.8 Where required by *Vol 2, Pt 9, Ch 4, 5.1 General 5.1.1*, the hazards resulting from electric arcs within electrical equipment and their consequences for personnel are to be identified, and at least the following supporting evidence is to be submitted:

(a) system design;
(b) operating philosophies, e.g. manual or automatic control, local or remote operation;
(c) general arrangement plans for switchboards, section boards and distribution boards, *see also Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.18*;
(d) general arrangement plans for the space in which the electrical equipment to be assessed is located, showing:

- access to adjacent spaces;
- the location of the electrical equipment;
- ventilation arrangements for air conditioning and/or the extraction of smoke, gas and vapours resulting from electric arcs;

- positions within the space in which the electrical equipment is located where personnel will be performing tasks, e.g. switching, equipment maintenance, instrument observation or cleaning, or where personnel could reasonably be expected to enter;

(e) calculations in accordance with *Vol 2, Pt 9, Ch 4, 5.3 Calculations to be submitted*;
(f) system operating procedures; and
(g) details of defined additional safety measures to be taken during activities.

1.4.9 For naval ships in which explosive gas atmospheres may occur, the spaces are to be identified.

1.4.10 A schedule of electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts giving details, as appropriate, of:

(a) type of equipment;
(b) type of protection, e.g. Ex ‘d’;
(c) apparatus group, e.g. IIB;
(d) temperature class, e.g. T3;
(e) enclosure ingress protection, e.g. IP55;
(f) certifying authority;
(g) certificate number;
(h) location of equipment.

Details may be included on arrangement drawings for the hazardous locations, in place of a separate schedule. Where uncertified equipment is permitted by *Vol 2, Pt 9, Ch 5, 4.2 Selection of equipment for use in explosive gas atmospheres* or *Vol 2, Pt 9, Ch 5, 4.3 Selection of equipment for use in the presence of combustible dusts* or the Rules relevant to the specific type of ship, details of other documentation confirming (b) to (d) may be submitted in place of those listed under *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.10* and *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.10*.

1.4.11 Simplified circuit diagram of electrical propulsion system (where fitted) giving details of:

(a) ratings of electrical machines, transformers, batteries, dynamic braking assemblies and semiconductor converters;
(b) lubrication and cooling arrangements, where provided;
(c) insulation type, size and current loadings of cables;
(d) make, type and rating of circuit breakers and fuses;
(e) instrumentation and protective devices;
(f) earth fault indication/protection;
(g) propulsion control systems, and the procedures used to ensure that there is satisfactory control of the design in relation to the requirements of *Vol 2, Pt 4, Ch 5, 4.4 Propulsion control*; and
(h) harmonic analysis.

1.4.12 Details of electrically operated fire, ship, crew and embarked personnel emergency safety systems which are to include typical single line diagrams and arrangements, showing main vertical and, where applicable, horizontal fire zones, spaces along the ship bottom that are not fitted with a double bottom and the location of equipment and cable, including identification of relevant areas of high fire risk, to be employed for:

(a) emergency lighting (other than where accumulator emergency lanterns are to be installed);
(b) accommodation fire detection, alarm and extinction systems;
(c) fixed water-based local application fire-fighting systems;
(d) crew and embarked personnel address system;
(e) general emergency alarm;
(f) watertight doors, bow, stern and shell doors and other electrically operated closing appliances; and
(g) low location lighting.

Note A general arrangement plan of the complete ship showing the main vertical fire zones, spaces along the ship bottom that are not fitted with a double bottom and the location of equipment and cable routes, including identification of relevant areas of high fire risk, for the above systems, is to be made available for the use of the Surveyor on board.

1.4.13 Evidence of the suitability of electrical and electronic equipment for use in protected areas and adjacent areas, as required by *Vol 2, Pt 9, Ch 9, 5.2 Fixed water-based local application fire-fighting systems 5.2.16* and *Vol 2, Pt 9, Ch 9, 5.2 Fixed water-based local application fire-fighting systems 5.2.16*, including a schedule of electrical and electronic equipment located in

protected areas and adjacent areas and general arrangement plans showing the coverage of the protected areas and adjacent areas.

1.4.14 A test schedule for both works testing, harbour trials and sea trials is to include the method of testing and the test facilities which are provided for the general emergency alarm system and the crew and embarked personnel address system.

1.4.15 Documented test procedures to demonstrate compliance with STANAG 1008, or a relevant and acceptable naval standard, where the electrical class notation **ELS** is required.

1.4.16 For battery installations, arrangement plans and calculations to show compliance with *Vol 2, Pt 9, Ch 2, 7.4 Installation*

1.4.17 A schedule of batteries fitted for use for emergency, Mobility and/or Ship Type systems, giving details of:

- type and manufacturer's type designation;
- voltage and ampere-hour rating;
- location;
- equipment and/or system(s) served;
- maintenance/replacement cycle dates;
- date(s) of maintenance and/or replacement; and
- for replacement batteries in storage, the date of manufacture and shelf life, with accompanying battery replacement procedure documentation to show compliance with *Vol 2, Pt 9, Ch 2, 7.7 Recording of batteries for emergency and essential services*.

Note The above includes all batteries fitted as part of an uninterruptible power system (UPS) used for any essential or emergency services.

1.4.18 General arrangement plans showing the location of propulsion generators, motors, transformers, semiconductor converters, dynamic braking equipment, reactors and filters. The information supplied is also to include cable routes to show compliance with *Vol 2, Pt 9, Ch 3, 8.8 Installation of electric cables*, as applicable.

1.4.19 Plans for all cables that pass through atria or equivalent spaces, and for vertical runs in trunks or other restricted spaces. The information supplied is to show compliance with *Vol 2, Pt 9, Ch 3, 8.8 Installation of electric cables 8.8.10*.

1.4.20 **Alarm systems**. Details of the overall alarm system linking the main control station, subsidiary control stations, the bridge area and accommodation including details of alerts to be presented by the user interface, with:

(a) an approach to alert category assignments which is in accordance with the IMO *Code on Alerts and Indicators, 2009*; and
(b) for alarms required by these Rules the intended Operator's response and the message are to be presented.

1.4.21 **Programmable electronic systems**. (In addition to the documentation required by *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.2*.)

(a) System requirements specification.
(b) Details of the hardware configuration in the form of a system block diagram, including input/output schedules.
(c) Details of power supply and data storage arrangements, *see Vol 2, Pt 9, Ch 8, 5.1 General requirements 5.1.10* and *Vol 2, Pt 9, Ch 8, 5.4 Additional requirements for Mobility category and safety critical systems 5.4.6*.
(d) Hardware certification details, *see Vol 2, Pt 9, Ch 8, 5.1 General requirements 5.1.6* and *Vol 2, Pt 9, Ch 8, 5.4 Additional requirements for Mobility category and safety critical systems 5.4.3*.
(e) Software quality plans, including applicable procedures, *see Vol 2, Pt 9, Ch 8, 5.1 General requirements 5.1.21*.
(f) Factory acceptance, integration, harbour and sea trial test schedules for hardware and software.
(g) System integration plan, *see Vol 2, Pt 9, Ch 8, 5.5 Additional requirements for integrated systems 5.5.2*.
(h) Risk Assessment (RA),*see Vol 2, Pt 9, Ch 8, 5.5 Additional requirements for integrated systems 5.5.5* and *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*.

1.4.22 For wireless data communication equipment:

(a) details of manufacturer’s installation and maintenance recommendations;
(b) network plan with arrangement and type of aerials and identification of location;
(c) specification of wireless communication system protocols and management functions, *see Vol 2, Pt 9, Ch 8, 5.3 Additional requirements for wireless data communication links 5.3.4*;
(d) details of radio frequency and power levels, including details of those permitted by the National Administration.

1.4.23 Plans showing the location and details of control stations, e.g. control panels and consoles. Location and details of controls and displays on each panel. Detailed user interface specifications. A general arrangement plan of control rooms showing the position of consoles, handrails, operator area, lighting, door and window arrangements. Drawing of HVAC systems including vent arrangements.

1.4.24 **Fire detection systems**. Plans showing the system operation and the type and location of all machinery space fire detector heads, manual call points and the fire detector indicator panel(s). The plans are to indicate the position of the fire detectors in relation to significant items of machinery, ventilation and extraction openings.

1.4.25 **Test schedules**. Test schedules for works testing, factory acceptance tests, harbour testing and sea trials, which should include methods of testing and test facilities, *see Vol 2, Pt 9, Ch 11, 1.8 Record of trials 1.8.1*.

1.4.26 **Lifts**. For details of alarms and safeguards for lifts classed by LR, reference should be made to LR's *Code for Lifting Appliances in a Marine Environment, November 2015* .

1.5 Documentation required for supporting evidence

1.5.1 The documentation in *Vol 2, Pt 9, Ch 1, 1.5 Documentation required for supporting evidence 1.5.2* is to be submitted as supporting evidence.

1.5.2 In order to establish compliance with *Vol 2, Pt 9, Ch 1, 2.2 Design, construction and location 2.2.7* and *Vol 2, Pt 9, Ch 3, 4.1 Systems of supply and distribution 4.1.5*, a general arrangement plan of the ship showing the location of major items of electrical equipment, for example:

- main and emergency generators;
- switchboards;
- section boards and distribution boards supplying Mobility and/or Ship Type systems, and emergency services;
- emergency batteries;
- motors for emergency services; and
- cable routes between these items of equipment.

1.5.3 Arrangement plans of main and emergency switchboards and section boards, and documentation that demonstrates that creepage and clearance distances are in accordance with *Vol 2, Pt 9, Ch 3, 5.7 Creepage and clearance distances*. The form factor of internal separation of low voltage switchgear and controlgear assemblies is to be in accordance with IEC 61439-2, *Low-voltage switchgear and controlgear assemblies – Part 2: Power switchgear and controlgear assemblies*, or an alternative acceptable and relevant national Standard. The form factor is to be stated, and the arrangement plans are to show how the form factor has been achieved.

1.5.4 A Risk Assessment (RA), in accordance with *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*, is required to be submitted, *see Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.7*. The RA is to verify the availability of electrical power to Mobility and/or Ship Type systems in the event of a failure of a system or item of equipment, *see Vol 2, Pt 9, Ch 3, 4.2 Essential services 4.2.4*.

1.5.5 In order to establish compliance with the requirements of *Vol 2, Pt 9, Ch 1, 2.2 Design, construction and location 2.2.3*, when requested, evidence is to be submitted to demonstrate the suitability of electrical equipment for its intended purpose in the conditions in which it is expected to operate.

1.5.6 Where deviation from the specific requirements of these Rules is required, details of the arrangements with documented justification and/or analysis are to be submitted, *see Vol 2, Pt 9, Ch 1, 1.2 Application 1.2.4*

1.5.7 **Cables**. For details of instrumentation and control requirements.

1.6 Surveys

1.6.1 Electrical propelling machinery and associated equipment together with auxiliary services essential for the safety of the ship are to be installed in accordance with the relevant requirements of this Chapter, surveyed and have tests witnessed by the Surveyors.

1.6.2 The following equipment, where intended for use for Mobility systems, Ship Type systems, and/or emergency services, is to be surveyed by the Surveyors during manufacture and testing:

- Converting equipment of 100 kW and over;
- Rotating machines of 100 kW and over;
- Switchboards and section boards; and

- UPS units of 50 kVA and over.

1.6.3 For electric propulsion systems, in addition to the equipment listed in *Vol 2, Pt 9, Ch 1, 1.6 Surveys 1.6.2*, the following equipment is to be surveyed by the Surveyors during manufacture and testing:

- cables, *see Vol 2, Pt 9, Ch 3, 8.1 General 8.1.6*;
- exciters;
- filters;
- reactors;
- dynamic braking assemblies;
- pre-magnetisation transformers; and
- slip ring assemblies.

1.6.4 Equipment associated with control, alarm and safety functions for systems listed in *Vol 2, Pt 9, Ch 1, 1.1 Scope 1.1.1* are to be surveyed at the manufacturers' works in accordance with the approved test schedule (*see Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.25*), and the inspection and testing are to be to the Surveyor's satisfaction, *see Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.2*.

1.6.5 All other electrical equipment, not specifically referenced in *Vol 2, Pt 9, Ch 1, 1.6 Surveys 1.6.2* and *Vol 2, Pt 9, Ch 1, 1.6 Surveys 1.6.4*, intended for use for Mobility systems, Ship Type systems, or emergency services is to be supplied with a manufacturer's works test certificate showing compliance with the constructional standard(s) as referenced by the relevant requirements of the Chapter.

1.7 Alterations and additions

1.7.1 When an alteration or addition to the approved system(s) is proposed, plans are to be submitted for approval. The alterations or additions are to be carried out under survey and the installation and testing are to be to the Surveyor's satisfaction.

1.7.2 No addition, temporary or permanent, is to be made to the approved load of an existing installation until it has been ascertained that the current carrying capacity and the condition of the existing equipment including cables and switchgear are adequate for the increased load.

1.7.3 Details of proposed software modifications are to be submitted for consideration. Modifications are to be undertaken in accordance with defined modification processes which are part of the supplier's or system integrator's quality management system. The quality management system is to be acceptable to LR, *see Vol 2, Pt 1, Ch 1, 8 Quality assurance scheme for machinery*. The following documentation is to be submitted:

(a) Project-specific software modification plan.
(b) An impact analysis which identifies the effect(s) of the proposed modification. The results of the analysis are to be used to inform the extent of verification and validation that is to be applied. This analysis is to consider both the local impact and, where applicable, the system level impact of the modification.
(c) Configuration management records that satisfy the requirements of ISO 10007, to demonstrate the traceability of the proposed modification.
(d) Factory acceptance, integration and sea trial test schedules as determined by the impact analysis in (b).
(e) Updated documentation as detailed in *Vol 2, Pt 9, Ch 1, 1.2 Application 1.2.6*.

1.7.4 Verification and validation activities are to demonstrate that the modified functionality performs as expected and that the modification has not unintentionally modified functionality outside the scope of the modification.

1.7.5 Software versions are to be uniquely identified by number, date or other appropriate means. Modifications are not to be made without also changing the version identifier. A record of changes to the system since the original issue (and their identification) is to be maintained and made available to the LR Surveyor on request.

1.7.6 Proposed modifications to the electrical protection systems are to be developed in accordance with *Vol 2, Pt 9, Ch 4, 4.1 General 4.1.4* and plans submitted are also to address the updating of the approved version of the details required by *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.6* and *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.7*.

1.7.7 When it is proposed to replace permanently installed secondary valve-regulated sealed batteries with vented batteries, details are to be submitted for consideration to ensure continued safety in the presence of the products of electrolysis and evaporation being allowed to escape freely from the cells to the atmosphere. These details are to demonstrate that there will be

adequate ventilation in accordance with *Vol 2, Pt 9, Ch 2, 7.5 Ventilation 7.5.9* and that the location and installation requirements of *Vol 2, Pt 9, Ch 2, 7.3 Location* and *Vol 2, Pt 9, Ch 2, 7.4 Installation* are complied with.

1.7.8 Where it is intended to replace an existing incandescent lamp type navigation light with a light emitting diode type navigation light, details are to be submitted for consideration that demonstrate compliance with *Vol 2, Pt 9, Ch 7, 4.7 Valve control and indication systems*. Light emitting diode type navigation lights failure detection arrangements are additionally to satisfy the requirements of *Vol 2, Pt 9, Ch 7, 4.7 Valve control and indication systems 4.7.5* and *Vol 2, Pt 9, Ch 7, 4.7 Valve control and indication systems 4.7.6*.

■ *Section 2* System level requirements

2.1 Quality of power supplies (QPS)

2.1.1 All electrical equipment supplied from the main and emergency sources of electrical power and electrical equipment for Mobility systems, Ship Type systems, and emergency services supplied from d.c. sources of electrical power is to be so designed and manufactured that it is capable of operating satisfactorily under normally occurring variations of voltage and frequency.

2.1.2 Unless specified otherwise, a.c. electrical equipment is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals:

(a) voltage:

permanent variations +6%, -10%

transient variations due to step changes in load ±20%

recovery time 1,5 seconds

(b) frequency:

permanent variations ±5%

transient variations due to step changes in load ±10%

recovery time 5 seconds

A maximum rate of change of frequency not exceeding ±1,5 Hz per second during cyclic frequency fluctuations.

2.1.3 **Harmonics**. Unless specified otherwise, the total harmonic distortion (THD) of the voltage waveform at any switchboard or section-board is not to exceed 8 per cent of the fundamental for all frequencies up to 50 times the supply frequency and no voltage at a frequency above 25 times supply frequency is to exceed 1,5 per cent of the fundamental of the supply voltage. THD is the ratio of the rms value of the harmonic content to the rms value of the fundamental, expressed in per cent and may be calculated using the expression:

$$THD = \frac{\sqrt{\sum_{h=2}^{\infty} V_h{}^2}}{V_1} \times 100$$

where

V_h = rms amplitude of a harmonic voltage of order *h*

V_1 = rms amplitude of the fundamental voltage.

2.1.4 Unless specified otherwise, d.c. electrical equipment is to operate satisfactorily with the following simultaneous variations, from their nominal value, when measured at the consumer input terminals:

(a) When supplied by d.c. generator(s) or a rectified a.c. supply:

Voltage tolerance (continuous)	±10%
Voltage cyclic variation deviation	5%

Voltage ripple	10%
(a.c. rms over steady state d.c. voltage)	

(b) When supplied by batteries:

(i) Equipment connected to the batteries during charging: Voltage tolerance +30%, -25%;

(ii) Equipment not connected to batteries during charging: Voltage tolerance +20%, -25%.

Different voltage variations as determined by the charging/discharging characteristics, including ripple voltage from the charging device, may be considered. When battery chargers/battery combinations are used as d.c. power supply systems, adequate measures are to be taken to keep the voltage within the specified limits during charging, boost charging and discharging of the battery.

2.1.5 Where the electrical class notation **ELS** is to be assigned, *see Vol 2, Pt 9, Ch 1, 3 Quality of power supplies – ELS notation*.

2.1.6 Where weapons or other combat systems may degrade the quality of power supplies, relevant details are to be advised to LR and to the prime contractor in order that the consequences may be established.

2.2 Design, construction and location

2.2.1 Electrical propelling machinery and associated equipment together with equipment for services essential for the propulsion and safety of the ship are to be constructed in accordance with the relevant requirements of this Chapter.

2.2.2 The design and installation of all equipment is to be such that risk of fire due to its failure is minimised. It is, as a minimum, to comply with a National or International Standard revised where necessary for ambient conditions.

2.2.3 Electrical equipment is to be suitable for its intended purpose in all conditions in which it is expected to operate. Equipment is to be designed and constructed in accordance with agreed specified standards. The design and construction is to take account of both functional and environmental requirements. For details of marine environmental conditions, reference should be made to Annex B of IEC 60092: *Electrical installations in ships - Part 101: Definitions and general requirements*.

2.2.4 For areas susceptible to deluge or submersion, cable entries are to prevent water ingress. In general, cable entries are to be in accordance with IEC 60092-101, *Electrical Installations in Ships – Part 101: Definitions and General Requirements.*

2.2.5 Where equipment intended for Mobility or Ship Type systems requires a controlled environment, an alternative means is to be provided to maintain the required environment in the event of a failure of the normal cooling system. Failure of the cooling system is to initiate an alarm. Duplication of the equipment requiring cooling can be provided instead of an alternative means of cooling, providing that the duplicated equipment is fed from an alternative, independent cooling system.

2.2.6 Assessment of performance parameters, such as accuracy, repeatability, etc. are to be in accordance with an acceptable specialised naval standard, national or international standard, e.g. IEC 60051, *Direct acting indicating analogue electrical measuring instruments and their accessories.*

2.2.7 Special consideration will be given to arrangements that comply with a relevant and acceptable specialised Naval, National or International Standard, such as IEC 60092-504, *Electrical Installation on Ships – Special Features: Control and Instrumentation*.

2.2.8 All electrical equipment is be constructed or selected and installed such that:

(a) live parts cannot be inadvertently touched, unless they are supplies at the safety voltage specified in *Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding 2.4.2*;

(b) it does not cause injury when handled or touched in the normal manner; and

(c) it is unaffected by any water, steam or oil and oil vapour to which it is likely to be exposed.

Where not exposed to direct liquid spray, electrical equipment having, as a minimum, the degrees of protection as specified in IEC 60092-201 for the relevant location will satisfy these requirements. Where the equipment may be exposed to direct liquid spray the degree of protection is not to be less than IPX4. Where the equipment may be exposed to possible liquid immersion, the degree of protection is not to be less than IPX7.

2.2.9 Switchboards, section boards and distribution boards supplying Mobility or Ship Type systems, and emergency services, as well as cables from the respective generators to and between these boards, are to be arranged to avoid areas of high fire risk and elevated temperatures, for example, in close proximity to incinerators and boilers.

2.2.10 Electrical equipment, as far as is practicable, is to be located:

(a) such that it is accessible for the purpose of maintenance and survey;

(b) clear of flammable material;

(c) in spaces adequately ventilated to remove the waste heat liberated by the equipment under full load conditions, at the ambient conditions specified in *Vol 2, Pt 9, Ch 1, 2.3 Ambient reference and operating conditions*;

(d) where flammable gases cannot accumulate. If this is not practicable, electrical equipment is to be of the appropriate 'safe type', *see Vol 2, Pt 9, Ch 5, 4 Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts*;

(e) where it is not exposed to the risk of mechanical injury or damage from water, steam or oil.

2.2.11 Equipment design and the choice of materials are to reduce the likelihood of fire, ensuring that:

(a) where the electrical energised part can cause ignition and fire, it is contained within the bounds of the enclosure of the electrotechnical product;

(b) the design, material(s) and construction of the enclosure minimises, as far as is practicable, any internal ignition causing ignition of adjacent materials; and

(c) where surfaces of the electrotechnical products can be exposed to external fire, they do not, as far as practicable, contribute to the fire growth.

Note Compliance with IEC 60695;*Fire hazard testing (all parts)*, or an alternative and acceptable standard, will satisfy this requirement, *see also Vol 2, Pt 9, Ch 3, 8.10 Cable support systems 8.10.7*.

2.2.12 Insulating materials and insulated windings are to be oil resistant to tracking, moisture, sea air, oil and oil vapour unless special precautions are taken to protect them.

2.2.13 The minimum creepage and clearance distances provided for electrical connections, terminals and similar bare live parts are to be in accordance with a relevant International or National Standard for the equipment or apparatus concerned. In cases where the rated voltage is outside that given in the Standard or where no Standard is available, the minimum creepage and clearance distances provided are to be in accordance with *Vol 2, Pt 9, Ch 3, 5.7 Creepage and clearance distances*. Details of alternative proposals including supporting design rationale and demonstration may be submitted for consideration.

2.2.14 Studs, screw-type of spring-type clamp terminations, satisfactory for the normal operating currents and voltages, are to be provided in electrical equipment for the connection of external cable, or bus-bar conductors, as appropriate, *see also Vol 2, Pt 9, Ch 3, 8.15 Electric cable ends*. There is to be adequate space and access for the terminations.

2.2.15 The design of equipment is to enable ease of access to all parts requiring inspection or replacement in service.

2.2.16 Equipment is not to remain live through the control circuits and/or pilot lamps when switched off by the control switch. This does not apply to synchronising switches and/or plugs. Where equipment such as anti-condensation heaters is fed from a supply separate from the main supply, isolation arrangements are to be provided.

2.2.17 The operation of all electrical equipment and the lubrication arrangements are to be efficient under such conditions of vibration and shock as arise in normal practice. This requirement excludes military aspects that are required to be defined by *Vol 2, Pt 1, Ch 3, 4.9 Military requirements*

2.2.18 All nuts and screws and clamping devices used in connection with current-carrying, supporting and working parts are to be provided with means to ensure that they cannot work loose by vibration and shock as arise in normal practice.

2.2.19 To allow ease of access, connectors are to be spaced far enough apart to permit connection and disconnection. At test points, adequate clearance is to be provided between connection points and controls to provide access for testing.

2.2.20 Conductors and equipment are to be placed at such a distance from the magnetic compasses, or are to be so disposed, that the interfering magnetic field is negligible when circuits are switched on and off.

2.2.21 Where electrical power is used for propulsion, the equipment is to be so arranged that it will operate satisfactorily in the event of partial flooding by bilge water above the tank top up to the bottom floor plate level under the normal angles of inclination given in *Vol 2, Pt 9, Ch 1, 2.3 Ambient reference and operating conditions* for Mobility systems, *see Vol 2, Pt 7, Ch 2, 4 Drainage of machinery spaces*. This requirement excludes military aspects that are required to be defined by *Vol 2, Pt 1, Ch 3, 4.9 Military requirements*.

2.2.22 Cables for emergency alarms and their power sources are to be in accordance with *Vol 2, Pt 9, Ch 1, 2.5 Operation under fire conditions*.

2.2.23 Electrical equipment and cables for emergency alarms are to be so arranged that the loss of alarms in any one area due to localised fire, collision, flooding or similar damage is minimised, *see Vol 2, Pt 9, Ch 1, 2.8 Labels, signs and notices*and *Vol 2, Pt 9, Ch 1, 2.5 Operation under fire conditions*.

2.3 Ambient reference and operating conditions

2.3.1 Reference is to be made to*Vol 2, Pt 1, Ch 3, 4.4 Ambient reference conditions* and *Vol 2, Pt 1, Ch 3, 4.5 Ambient operating conditions* for the requirements concerning: Ambient reference conditions and Ambient operating conditions, with regards to the rating of Mobility and/or Ship Type electrical equipment for classification of restricted and unrestricted service conditions, and satisfactory operating conditions of machinery Mobility and/or Ship Type systems.

2.3.2 Where electrical equipment is installed within environmentally controlled spaces, the ambient temperature for which the equipment is suitable for operation at its rated capacity may be reduced to a value not less than 35°C provided:

- the equipment is not for use for emergency services and is located outside of machinery space(s);
- temperature control is achieved by at least two cooling units so arranged that in the event of loss of one cooling unit, for any reason, the remaining unit(s) is (are) capable of satisfactorily maintaining the design temperature;
- the equipment is able to be initially set to work safety within a 45°C ambient temperature until such a time that the lesser ambient temperature may be achieved; the cooling equipment is to be rated for a 45°C ambient temperature;
- alarms are provided, at a continually attended control station, to indicate any malfunction of the cooling units.

2.3.3 Where equipment is to comply with *Vol 2, Pt 9, Ch 1, 2.3 Ambient reference and operating conditions 2.3.2*, it is to be ensured that electrical cables for their entire length are adequately rated for the maximum ambient temperature to which they are exposed along their length.

2.3.4 Equipment used for cooling and maintaining the lesser ambient temperature in accordance with *Vol 2, Pt 9, Ch 1, 2.3 Ambient reference and operating conditions 2.3.2* are considered Mobility or Ship Type systems and are to satisfy the requirements of *Vol 2, Pt 9, Ch 3, 4.2 Essential services 4.2.1*.

2.4 Earthing and bonding

2.4.1 Except where exempted by *Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding 2.4.2*, all non-current carrying exposed metal parts of electrical equipment and cables are to be earthed for personnel protection against electric shock. Bonding is to give a substantially equal potential and a sufficiently low earth fault loop impedance to ensure correct operation of protective devices.

2.4.2 The following parts may be exempted from the requirements of *Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding 2.4.1*:

(a) lamp-caps, where suitably shrouded;
(b) shades, reflectors and guards supported on lampholders or light fittings constructed of, or shrouded in, non-conducting material;
(c) metal parts on, or screws in or through, non-conducting materials, which are separated by such material from current-carrying parts and from earthed non-current carrying parts in such a way that in normal use they cannot become live or come into contact with earthed parts;
(d) apparatus which is constructed in accordance with the principle of double insulation;
(e) bearing housings which are insulated in order to prevent circulation of current in the bearings;
(f) clips for fluorescent lamps;
(g) cable clips and short lengths of pipes for cable protection;
(h) apparatus supplied at a safety voltage not exceeding 55 V direct current or 55 V, root mean square, between conductors, or between any conductor and earth in a circuit isolated from the supply. Autotransformers are not to be used for the purpose of achieving the alternating current voltage;
(i) apparatus or parts of apparatus which although not shrouded in insulating material is nevertheless otherwise so guarded that it cannot be touched and cannot come in contact with exposed metal.

2.4.3 Where extraneous-conductive parts (i.e. parts not forming part of the electrical installation and liable to introduce an electric potential) are not bonded by separate earthing conductors, details are to be submitted that demonstrate that a permanent, metal-to-metal connection of negligible impedance, which will not degrade due to corrosion or vibration, will be achieved.

2.4.4 Armouring, braiding and other metal coverings are to be effectively earthed. Where the armouring, braiding and other metal coverings are earthed at one end only, they are to be adequately protected and insulated at the unearthed end with the insulation being suitable for the maximum voltage that may be induced. *See Vol 2, Pt 9, Ch 5, 4.9 Cable and cable installation 4.9.2* for earthing of cables in hazardous zones or spaces.

2.4.5 The electrical continuity of all metal coverings of cables throughout the length of the cable, particularly at joints and tappings, is to be ensured.

2.4.6 Earthing conductors are to be of copper or other corrosion-resistant material and be securely installed and protected where necessary against damage and also, where necessary, against electrolytic corrosion. Connections are to be so secured that they cannot work loose under vibration. It is recommended that earthing conductors carrying RF currents should be solid strip, not braid, to minimise the impedance.

2.4.7 The nominal cross-section areas of copper earthing conductors for electrical equipment are, in general to be equal to the cross-section of the current-carrying conductor up to 16 mm^2, with a minimum of 1,5 mm^2. Above this figure they are to be equal to at least half the cross-section of the current-carrying conductor with a minimum of 16 mm^2.

2.4.8 The nominal cross-sectional areas of copper earthing conductors for amouring, braiding and other metal coverings of cables are, in general, to be equal to the equivalent cross-section of the armouring, braiding and other metal coverings with a minimum of 1,5 mm^2.

2.4.9 Earthing conductors of materials other than copper are to have a conductance not less than that specified for an equivalent copper earthing conductor.

2.4.10 The connection of the earthing conductor to the hull of the ship is to be made in an accessible position, and is to be secured by a screw or stud of a diameter appropriate for the size of the earthing conductor, but not less than 6 mm which is to be used for this purpose only. Bright metallic surfaces at the contact areas are to be ensured immediately before the nut or screw is tightened and, where necessary, the joint is to be protected against electrolytic corrosion. The connection is to remain unpainted.

2.4.11 Bonding straps for the control of static electricity are required for refuelling tanks and piping systems, for flammable products and solids liable to release flammable gas and/or combustible dust, which are not permanently connected to the hull of the ship either directly or via their bolted or welded supports and where the resistance between them and the hull exceeds 1MΩ.

2.4.12 Where bonding straps are required for the control of static electricity, they are to be robust, that is, having a cross-sectional area of at least 10 mm^2, and are to comply with *Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding 2.4.6* and *Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding 2.4.10*.

2.5 Operation under fire conditions

2.5.1 As a minimum, the following emergency services and their emergency power supplies are required to be capable of being operated under fire conditions:

- Emergency fire pump.
- Control and power systems to power-operated fire doors and status indication for all fire doors.
- Control and power systems to power-operated watertight doors and their status indication.
- Emergency lighting.
- Fire and general emergency alarms.
- Fire detection systems.
- Fire-extinguishing systems and fire-extinguishing media release alarms.
- Fire safety stops, *see also Vol 2, Pt 9, Ch 5, 4.9 Cable and cable installation 4.9.2*.
- Low location lighting, *see also Vol 2, Pt 9, Ch 6, 4.6 Escape route or low location lighting (LLL) 4.6.3*
- Crew and embarked personnel address systems.

2.5.2 Where cables for the emergency services listed in *Vol 2, Pt 9, Ch 1, 2.5 Operation under fire conditions 2.5.1* pass through high fire risk areas, main vertical or horizontal fire zones other than those which they serve, they are to be so arranged that a fire in any of these areas or zones does not affect the operation of the emergency service in any other area or zone. This may be achieved either by:

- cables being of a fire-resistant type complying with *Vol 2, Pt 9, Ch 3, 8.5 Construction 8.5.3*, and at least extending from the main control/monitoring panel to the nearest local distribution panel serving the relevant area or zone; or
- there being at least two-loops/radial distributions run as widely apart as is practicable and so arranged that in the event of damage by fire at least one of the loops/radial distributions remains operational.

Areas of high fire risk include:

(a) Machinery spaces including diesel generator compartments and gas turbine compartments but excluding those spaces which do not contain machinery having a pressure lubrication system and where the storage of combustibles is prohibited.

(b) Galleys.

(c) Compartments with tanks containing flammable liquids with a flash point lower than 60°C or with a temperature above 32°C.

(d) Compartments containing liquid oxygen.

(e) Fuel, petrol, oil or lubricant pump spaces.

(f) Magazines for munitions and armaments.

2.5.3 Where the cables for the power supplies for the emergency services listed in *Vol 2, Pt 9, Ch 1, 2.5 Operation under fire conditions 2.5.1* pass through high fire risk areas, main vertical or horizontal fire zones other than those which they serve, they are to be of a fire resistant type complying with *Vol 2, Pt 9, Ch 3, 8.5 Construction 8.5.3*, extending at least to the local distribution panel serving the relevant area or zone.

2.5.4 Fire-resistant electrical cables for the emergency services listed in *Vol 2, Pt 9, Ch 1, 2.5 Operation under fire conditions 2.5.1*, including their power supplies, are to be run as directly as is practicable, having regard to any special installation requirements, for example those concerning minimum bend radii.

2.6 Operation under flooding conditions

2.6.1 Flooding of spaces along the ship bottom that are not fitted with a double bottom is not to result in the loss of the ability to provide electrically operated fire, ship, crew and embarked personnel emergency safety systems outside of the spaces.

2.6.2 Installation of electrical equipment necessary to provide fire, ship, crew and embarked personnel emergency safety systems in spaces along the ship bottom not fitted with a double bottom is to be avoided, wherever practical. Where it is proposed to install electrical equipment, including cabling, necessary to provide fire, ship, crew and embarked personnel emergency safety systems in such spaces, evidence is to be submitted to demonstrate that required emergency services will be available in other spaces in the event of flooding of the space not fitted with a double bottom.

2.7 Electrical supplies to systems fulfilling military requirement

2.7.1 With the exception of dedicated electrical supplies to systems fulfilling military requirements, all other electrical supplies are to comply with these Rules. The Rules are applicable to electrical equipment and systems to the point of isolation of the military system or equipment. The point of isolation is the supply side of the isolating switch, MCCB panel, fuse panel or distribution panel dedicated to the military system or equipment.

2.7.2 Dedicated electrical supply arrangements to military systems are to be in accordance with recognised International/National/specialised naval standards.

2.7.3 Where isolating equipment is used for both military and other services, the Rule requirements are to be applied.

2.7.4 Automatic, hand and emergency changeover switches to military systems on the ship’s supply system are to comply with these Rules.

2.8 Labels, signs and notices

2.8.1 Labels, signs and notices required by this Chapter are to be positioned in clearly visible locations which will not be obscured.

2.8.2 Labels, signs and notices are to be easy to read under the expected operating conditions. Character height in accordance with *Table 1.2.1 Character height and viewing distance* will be considered to satisfy this requirement.

Table 1.2.1 Character height and viewing distance

Viewing distance (mm)	Minimum character height (mm)
Less than 500	2,3
500–1000	4,7
1000–2000	9,4
2000–4000	19

2.8.3 Controls, indicators and displays required by this Chapter are to be labelled to indicate their function. Labels are to be positioned in a manner that associates the label with the item being labelled.

2.8.4 Labels, signs and notices are to use short, clear messages. In general, warning signs and notices are to comprise:

- a word signalling the gravity of the risk (e.g. Danger, Warning or Caution)

- a statement of the nature and/or consequence of the hazard, and wherever practical, an instruction giving appropriate behaviour to avoid the hazard.

■ Section 3
Quality of power supplies – ELS notation

3.1 General

3.1.1 Where electrical power for the designated loads in the System Design Description of *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.5*, is provided in accordance with the applicable provisions of a relevant and acceptable naval standard, such as STANAG 1008, the class notation **ELS** may be assigned.

3.2 General requirements

3.2.1 The electrical system is to be stable in all operating profiles defined in accordance with the System Operational Concept .

3.2.2 The quality of the power supplies for the loads listed in the System Operational Concept is to comply with the standard, in place of the limits specified by *Vol 2, Pt 9, Ch 1, 2.1 Quality of power supplies (QPS) 2.1.2* . This level of quality is to be present at the point where the load is connected to the electrical power system.

3.2.3 Where the main generation and the distribution power supplies are also required to comply with the standard, the main generation and distribution system is to be of an insulated type in compliance with *Vol 2, Pt 9, Ch 3, 4.4 Insulated distribution systems*. *See also Vol 2, Pt 9, Ch 3, 4.5 Earthed distribution systems 4.5.7*.

3.2.4 A systematic procedure incorporating verification and validation methods is to be used to ensure successful implementation of the defined standard. A quality plan is to be submitted that describes this procedure along with the results of the design validation providing:

- details of any power system analysis software and the input data used;
- a transient stability analysis, unless the generator and load characteristics indicated by *Vol 2, Pt 9, Ch 2, 6.4 Generator control* are shown to be representative of the system under consideration;
- a harmonic distortion analysis, if the sum of loads that distort the current waveform is greater than 1% of the short circuit power of the generating capacity.

3.2.5 Where a transient stability analysis demonstrates that the defined standard requirements can be satisfied by generator control requirements different to those specified by *Vol 2, Pt 9, Ch 2, 6.4 Generator control* , these may be accepted as equivalent to the Rules.

3.2.6 Unless it can be satisfactorily shown by the design verification and validation process that the requirements of the defined standard can be met, then measurements are to be taken as specified in *Vol 2, Pt 9, Ch 11, 1.2 Trials 1.2.8*.

■ Section 4
Unattended machinery space(s) — UMS notation

4.1 General

4.1.1 Where it is proposed to operate the following machinery in an unattended space, no matter what period is envisaged, the controls, alarms and safeguards required by the appropriate Chapters together with those given in *Vol 2, Pt 9, Ch 1, 4.2 Alarm systems for machinery* to *Vol 2, Pt 9, Ch 1, 4.7 Supply of electric power, general* are to be provided:

- Air compressors.
- Controllable pitch propellers and transverse thrust units.
- Electric generating plant.
- Incinerators.
- Fuel oil transfer and storage systems (purifiers and oil heaters).

- Mobility systems.
- Steam raising plant (boilers and their ancillary equipment).
- Thermal fluid heaters.

4.2 Alarm systems for machinery

4.2.1 An alarm system which will provide warning of faults in the machinery is to be installed. The system is to satisfy the requirements of *Vol 2, Pt 9, Ch 7, 4.3 Alarm systems, general requirements*.

4.2.2 An audible signal and visual indication of machinery alarms are to be relayed to the engineers’ accommodation so that engineering personnel are made aware that a fault has occurred.

4.2.3 The engineers' alarm required by *Vol 2, Pt 9, Ch 7, 4.2 Control stations for machinery 4.2.3* is to be activated automatically in the event that a machinery alarm has not been acknowledged in the space within a predetermined time.

4.2.4 An audible signal and visual indication of machinery alarms are to be relayed to the navigating bridge control station in such a way that the navigating officer of the watch is made aware when:

(a) a machinery fault has occurred;
(b) the machinery fault is being attended to; and
(c) the machinery fault has been rectified.

4.2.5 Group alarms may be arranged on the bridge to indicate machinery faults, but alarms associated with faults requiring speed or power reduction or the automatic shutdown of propulsion machinery are to be identified by separate group alarms or by individual alarms.

4.3 Bridge control for propulsion machinery

4.3.1 A bridge control system for the propulsion machinery is to be fitted. The system is to satisfy the requirements of *Vol 2, Pt 9, Ch 7, 4.6 Bridge control for main propulsion machinery*.

4.4 Control stations for machinery

4.4.1 A control station(s) is to be provided in the space and on the bridge which satisfies the requirements of *Vol 2, Pt 9, Ch 7, 4.2 Control stations for machinery*.

4.5 Fire detection alarm system

4.5.1 An automatic fire detection system is to be fitted in the space together with an audible and visual alarm system. The system is to satisfy the requirements of *Vol 2, Pt 9, Ch 9, 4.1 General*.

4.6 Bilge level detection

4.6.1 An alarm system is to be provided to warn when liquid in machinery space bilges has reached a predetermined level, and is to comply with *Vol 2, Pt 9, Ch 7, 4.3 Alarm systems, general requirements* This level is to be sufficiently low to prevent liquid from overflowing from the bilges onto the tank top. The number and location of detectors are to be such that accumulation of liquids will be detected at all angles of heel and trim.

4.6.2 Local or remote controls of any valve within the space serving a sea inlet, a discharge below the waterline, a dewatering system should be so sited as to be readily accessible and to allow adequate time for operation in case of influx of water to the space, having regard to the time which could be taken to reach and operate such controls.

4.6.3 Where the bilge pumps are arranged to start automatically, means are to be provided to indicate if the influx of liquids is greater than the pump capacity or, if the pump is operating more frequently than would be expected. Special attention should be given to oil pollution prevention requirements.

4.7 Supply of electric power, general

4.7.1 For naval ships operating with one generator set in service, arrangements are to be such that a standby generator will automatically start and connect to the switchboard in as short a time as practicable, but in any case within 45 seconds, on loss of the service generator. For naval ships operating with two or more generator sets in service, arrangements are to be such that on loss of one generator the remaining one(s) are to be adequate for continuity of Mobility and/or Ship Type systems. For the detailed requirements of these arrangements, *see Vol 2, Pt 9, Ch 2, 4.2 Number and rating of generators and converting equipment*

4.7.2 Alarms and safeguards are indicated in *Table 1.4.1 Electric system: alarms and safeguards*.

Table 1.4.1 Electric system: alarms and safeguards

Item	Alarm	Note
Bus-bar voltage	High and low	—
Bus-bar frequency	Low	—
Operation of load shedding	Warning	—
Generator cooling air temperature	High	For closed air circuit water cooled machines

■ *Section 5*
Machinery operated from a centralised control station – CCS notation

5.1 General requirements

5.1.1 Where it is proposed to install control, alarm and safety systems to the equipment listed in *Vol 2, Pt 9, Ch 1, 4.1 General 4.1.1* the applicable features contained in *Vol 2, Pt 9, Ch 7, 4 Essential features for control, alarm and safety systems* and *Vol 2, Pt 9, Ch 8, 4 General requirements* and *Vol 2, Pt 9, Ch 8, 5 Programmable electronic systems (PES)* are to be incorporated in the system design.

5.1.2 The arrangements are to be such that corrective actions can be taken at the control station in the event of machinery faults, e.g. stopping of machinery, starting of standby machinery, adjustment of operating parameters, etc. These actions may be effected by either remote manual or automatic control.

5.1.3 The controls, alarms and safeguards required by the appropriate Chapters and by *Vol 2, Pt 9, Ch 1, 4.6 Bilge level detection* together with a fire detection system satisfying the requirements of *Vol 2, Pt 9, Ch 9, 4.1 General* are to be provided.

5.1.4 Additional requirements for controls, alarms and safeguards are given in *Vol 2, Pt 9, Ch 1, 5.2 Centralised control station for machinery*.

5.2 Centralised control station for machinery

5.2.1 A centralised control station is to be provided at some suitable location, which satisfies the requirements of *Vol 2, Pt 9, Ch 1, 5.2 Centralised control station for machinery 5.2.2* to *Vol 2, Pt 9, Ch 1, 5.2 Centralised control station for machinery 5.2.7* and the ergonomics requirements of *Vol 2, Pt 10 Human Factors*

5.2.2 A system of alarm displays and controls is to be provided which readily ensures identification of faults in the machinery and satisfactory supervision of related equipment. The alarm and control systems are to satisfy the requirements of *Vol 2, Pt 9, Ch 7, 4.3 Alarm systems, general requirements* and *Vol 2, Pt 9, Ch 7, 4.5 Control systems, general requirements*, as applicable.

5.2.3 Indication of all essential parameters necessary for the safe and effective operation of the machinery is to be provided, e.g. temperatures, pressures, tank levels, speeds, powers, etc.

5.2.4 Indication of the operational status of running and standby machinery is to be provided.

5.2.5 At the centralised control station, means of communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery space are to be provided.

5.2.6 In addition to the communication required by *Vol 2, Pt 9, Ch 1, 5.2 Centralised control station for machinery 5.2.5*, a second means of communication is to be provided between the bridge and the centralised control station. One of these means is to be independent of the main electrical power supply.

5.2.7 Arrangements are to be provided in the centralised control station so that the normal supply of electrical power may be restored in the event of failure.

■ Section 6
Integrated computer control - ICC notation

6.1 General

6.1.1 Integrated Computer Control class notation **ICC** may be assigned where an integrated computer system in compliance with *Vol 2, Pt 9, Ch 1, 6.1 General* to *Vol 2, Pt 9, Ch 1, 6.3 Operator stations* provides fault tolerant control and monitoring functions for one or more of the following services:

(a) Propulsion.

(b) Electrical generation and distribution (power management systems).

(c) Ballast.

6.1.2 A Risk Assessment (RA) is to be carried out in accordance with *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)* and the report and worksheets submitted for consideration, *see also Vol 2, Pt 9, Ch 8, 5.5 Additional requirements for integrated systems 5.5.5*. The RA is to demonstrate that control and monitoring functions required by *Vol 2, Pt 9, Ch 1, 6.2 General requirements* will remain available at each operator station in the event of a single fault of the integrated computer control system, including input error, without adverse effect on the service(s).

6.1.3 Special consideration will be given to integrated computer control systems for other applications, except where these are addressed by other control engineering class notations.

6.2 General requirements

6.2.1 The integrated computer control system is to comply with the programmable electronic system requirements of *Vol 2, Pt 9, Ch 8, 5 Programmable electronic systems (PES)* and the control and monitoring requirements of the Rules applicable to particular equipment, machinery or systems.

6.2.2 Alarm displays are to be provided, in compliance with the requirements of *Vol 2, Pt 9, Ch 7, 4.3 Alarm systems, general requirements*, which ensure ready identification of faults in the equipment under control.

6.2.3 Alarm and indication functions required by*Vol 2, Pt 9, Ch 7, 4.5 Control systems, general requirements* are to be provided by the integrated computer control system in response to the activation of any safety function for associated machinery. Systems providing the safety functions are in general to be independent of the integrated computer system. *See also Vol 2, Pt 9, Ch 8, 5.4 Additional requirements for Mobility category and safety critical systems 5.4.8*.

6.2.4 Controls are to be provided, in compliance with *Vol 2, Pt 9, Ch 7, 4.5 Control systems, general requirements*, to ensure the safe and effective operation of equipment and response to faults, e.g. stopping, starting, adjustment of parameters, etc. Indication of operational status and other such parameters, necessary to satisfy this requirement, is to be provided for all equipment under control by the integrated computer control system.

6.3 Operator stations

6.3.1 Each operator station allowing control of equipment is to be provided with a minimum of two multi-function display and control units and is to comply with the ergonomics requirements of *Vol 2, Pt 10 Human Factors*. The number of units is to be sufficient to allow simultaneous access to control and monitoring functions required by *Vol 2, Pt 9, Ch 1, 6.2 General requirements 6.2.2*to *Vol 2, Pt 9, Ch 1, 6.2 General requirements 6.2.4*. *See also Vol 2, Pt 9, Ch 8, 5.1 General requirements 5.1.21*.

6.3.2 Each multi-function display and control unit is to include a monitor, keyboard and tracker ball. Alternative arrangements will be considered where these enable each unit to be configured by the user to provide required control or monitoring functions.

6.3.3 Where the integrated computer control system is arranged such that control and monitoring functions may be accessed at more than one operator station, the selected mode of operation of each station (e.g. in control, standby, etc.) is to be clearly indicated. *See also Vol 2, Pt 9, Ch 7, 4.2 Control stations for machinery*.

6.3.4 Means of communication are to be provided between operator stations and any other stations from which the equipment may be controlled. The arrangements are to be permanently installed and are to remain operational in the event of failure of the main electrical power supply to the integrated control system.

Electrical Power Generator and Energy Storage

Volume 2, Part 9, Chapter 2

■ Scope

The requirements of this Chapter are applicable to the design and construction philosophy of electrical power generation and storage systems, including battery installations and generators driven by internal combustion engines, steam turbines and gas turbines.

This Chapter details the requirements for sub-systems and equipment within the boundary of electrical power system and is applicable for main and emergency auxiliary power generation as well as integrated electrical power generation and propulsion systems.

Application of this Chapter will facilitate the verification of the performance requirements of *ANEP-77, NATO Naval Ship Code*, Chapter IV, Regulation 9.

■ *Section 1* Functional requirements

1.1 Functional requirements

1.1.1 Provide sufficient electrical power to supply the required services and habitability requirements during all operational conditions without recourse to the emergency electrical supply.

1.1.2 Provide sufficient electrical power to services essential for safety during foreseeable abnormal and emergency conditions.

1.1.3 Provide transitional power supplies where no interruption of the electrical supply to services essential for safety is required.

1.1.4 Provide sufficient stored electrical energy to supply the services essential for safety during foreseeable abnormal and emergency conditions.

1.1.5 Provide sufficient electrical power for the purpose of emergency radio communications independent of the main and emergency (where provided) sources of electrical power.

Section 2
Performance requirements

2.1 Performance requirements

2.1.1 Arrangements shall be provided for the supply of electrical power sufficient to supply the required services and habitability during:

(a) All operational conditions;
(b) Irrespective of the direction of the propulsion shaft rotation;
(c) Without any recourse to the emergency source of electrical power.

2.1.2 System design intent shall provide for sufficient electrical power to supply Mobility systems, Ship Type systems, and habitable conditions in the event of loss or unavailability of any one generating set.

2.1.3 Suitable protection measures shall be provided in accordance with *Vol 2, Pt 9, Ch 4 Electrical Protection*.

2.1.4 No electrical equipment shall be put into use where its strength and capability may be exceeded in such a way as to give rise to danger or affect essential safety functions.

2.1.5 Where applicable, facilities to safely connect shore side electrical power shall be provided.

2.1.6 Means shall be provided to ensure that the propulsion machinery can be brought into operation following the loss of all means of electrical power generation using only sources of stored electrical power and without external aid.

2.1.7 Arrangements for the safe installation, use and maintenance of energy storage devices shall be provided.

2.1.8 In the event of failure of the main source of electrical power, a means to supply sufficient electricity to ensure the operation of all services essential for safety in an emergency shall be provided within a specified time and for a duration accepted by the Naval Administration.

2.1.9 Where no emergency generator is fitted, following the loss of a space due to fire or flooding, or loss of adjacent compartments, sufficient electrical power to supply services essential for safety in an emergency is to be available.

2.1.10 For essential safety functions for which an interruption to supply is unacceptable, transitional electrical supplies with sufficient capacity and duration accepted by the Naval Administration shall be provided.

Section 3
Verification requirements

3.1 General

3.1.1 Compliance with the requirements in *Vol 2, Pt 9, Ch 2, 4 Main source of electrical power* inclusive is deemed to satisfy the functional requirements and performance requirements above.

3.1.2 Where a designer offers a novel solution, an engineering safety and justification report is to be submitted. The engineering safety and justification report is to demonstrate how the proposed solution will satisfy the functional requirements and performance requirements in *Vol 2, Pt 9, Ch 2, 1 Functional requirements* and *Vol 2, Pt 9, Ch 2, 2 Performance requirements*.

3.1.3 The Naval Administration may impose requirements additional to those in this Chapter.

Section 4
Main source of electrical power

4.1 General

4.1.1 The main source of electrical power is to comply with the requirements of this section without recourse to the emergency source of electrical power.

4.2 Number and rating of generators and converting equipment

4.2.1 Under seagoing conditions, the number and rating of service generating sets and converting sets, such as transformers and semi-conductor converters, when any one generating set or converting set is out of action, are:

(a) to be sufficient to ensure the operation of electrical services for Mobility systems, Ship Type systems, and habitable conditions. *See Vol 2, Pt 4, Ch 5, 4.3 Power requirements 4.3.5* for electric propulsion systems;
(b) to have sufficient reserve capacity to permit the starting of the largest motor without causing any motor to trip, stall or any device to fail due to excessive voltage drop on the system;
(c) to be capable of providing the electrical services necessary to start the main propulsion machinery from a dead ship condition. The emergency source of electrical power may be used to assist if it can provide power at the same time to those services required to be supplied by *Vol 2, Pt 9, Ch 2, 5 Emergency and alternative sources of electrical power*

4.2.2 The arrangement of the ship's main source of power is to be such that the operation of electrical services for Mobility systems, Ship Type systems, and habitable conditions can be maintained regardless of the speed and direction of the propulsion machinery shafting.

4.2.3 Arrangements are to be provided to prevent overloading of the generating set(s) supplying the electrical power that is/are required to maintain the ship in a normal operational and habitable condition. On loss of electrical power, arrangements are to be made for a standby generator set to be started, connected to the switchboard and Mobility systems and Ship Type systems restarted in as short a time as is practicable. These load control, starting and restart functions may be achieved by the actions of suitably trained personnel but in ships with **UMS** notation the arrangements are to be automatic, *see also Vol 2, Pt 9, Ch 4, 4.9 Load management*.

4.3 Starting arrangements

4.3.1 The starting arrangements of the generating sets prime movers are to comply with the requirements of *Vol 2, Pt 2, Ch 1, 7 Starting arrangements* as applicable.

4.3.2 When the emergency source of electrical power is required to be used to restore propulsion from a dead ship condition, the emergency generator is to be capable of providing initial starting energy for the propulsion machinery within 30 minutes of the dead ship condition. The emergency generator capacity is to be sufficient for restoring propulsion in addition to supplying those services in *Vol 2, Pt 9, Ch 2, 5 Emergency and alternative sources of electrical power*. *See Vol 2, Pt 2, Ch 1, 7 Starting arrangements* for dead ship condition starting arrangements.

4.4 Prime mover governors

4.4.1 The governing accuracy of the generating sets prime movers is to meet the requirements of *Vol 2, Pt 2, Ch 1, 9.3 Auxiliary engine governors*

4.4.2 The maximum electrical step load switched on or off is not to cause the frequency variation of the electrical supply to exceed the parameters given in *Vol 2, Pt 9, Ch 1, 1.2 Application 1.2.1*.

4.5 Main propulsion driven generators not forming part of the main source of electrical power

4.5.1 Generators and generator systems, having the ship's propulsion machinery as their prime mover but not forming part of the ship's main source of electrical power may be used whilst the ship is at sea to supply electrical services required for normal operational and habitable conditions provided that the requirements of *Vol 2, Pt 9, Ch 2, 4.5 Main propulsion driven generators not forming part of the main source of electrical power 4.5.2* to *Vol 2, Pt 9, Ch 2, 4.5 Main propulsion driven generators not forming part of the main source of electrical power 4.5.4* are satisfied.

4.5.2 Within the declared operating range of the generators and/or generator system, the specified voltage and frequency variations of the Rules are to be met.

4.5.3 Where there is remote control of the propulsion machinery, arrangements are to ensure that Mobility machinery power supplies are maintained during manoeuvring conditions in order to prevent a blackout situation.

4.5.4 In addition to the requirements of *Vol 2, Pt 9, Ch 2, 4.2 Number and rating of generators and converting equipment 4.2.3*, arrangements are to be fitted to automatically start and connect one of the generators forming the main source of power should the frequency variations exceed those permitted by the Rules.

■ *Section 5*
Emergency and alternative sources of electrical power

5.1 General

5.1.1 The requirements of this Section apply to naval ships to be classed for unrestricted service. Alternative arrangements specified in accordance with the requirements of the Naval Administration may also be acceptable.

5.1.2 A greater or lesser period than the 18 hour period specified in *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7* may be considered in conjunction with the operational requirements as specified and any assigned Service Restriction.

5.1.3 Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, the installation is to comply with the requirements of *Vol 2, Pt 9, Ch 2, 5.5 Alternative sources of emergency electrical power*.

5.1.4 Where the main sources of electrical power are located in two or more compartments that are not contiguous with each other, and where each source has its own independent self-contained systems, including power distribution and control systems, such that a fire or casualty in any one of the compartments will not affect the power distribution from the other(s), or to the services required by *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7*, the requirement of this section will be satisfied without an additional emergency source of electrical power and its associated transitional source of power, provided that:

(a) there is at least one generating set complying with the requirements of *Vol 2, Pt 9, Ch 2, 4.2 Number and rating of generators and converting equipment* and of sufficient capacity to meet the requirements of *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7* in at least two non-contiguous compartments; and
(b) the generator sets referred to in *Vol 2, Pt 9, Ch 2, 5.1 General 5.1.4* and their self-contained systems are installed such that one of them remains operable and readily accessible after damage or flooding in any one compartment; and
(c) the generator sets referred to in *Vol 2, Pt 9, Ch 2, 5.1 General 5.1.4* are capable of being automatically started on loss of the power supplied by the other main source(s) of electrical power and supplying the services required by *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7* as quickly as is safe and practicable subject to a maximum of 45 seconds or provided with a transitional source of emergency electrical power as specified in *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.9*; and
(d) the number and arrangements of generators is to allow for maintenance at sea of any one generator without affecting the ability to supply electrical power to the services in *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7* from either of at least two compartments; and
(e) the requirements of this Chapter applicable to the emergency source or any associated equipment are to be applied to the main source complying with *Vol 2, Pt 9, Ch 2, 4.2 Number and rating of generators and converting equipment*, or any associated equipment.

5.2 Emergency source of electrical power

5.2.1 A self-contained emergency source of electrical power is to be provided.

5.2.2 The emergency source of electrical power, associated transforming equipment, if any, transitional source of emergency power, emergency switchboard and emergency lighting switchboard are to be located above the uppermost continuous deck and be readily accessible from the open deck. They are not to be located forward of the collision bulkhead.

5.2.3 The location of:

- the emergency source of electrical power and associated transforming equipment, if any;
- the transitional source of emergency power;
- the emergency switchboard; and

- the emergency lighting switchboard;

in relation to:

- the main source of electrical power, associated transforming equipment, if any; and
- the main switchboard;

is to be such as to ensure that a fire or other casualty in spaces containing:

- the main source of electrical power, associated transforming equipment, if any, and the main switchboard; or
- in any machinery space of Category A;

will not interfere with the supply, control and distribution of emergency electrical power.

5.2.4 The space containing:

- the emergency source of electrical power, associated transforming equipment, if any;
- the transitional source of emergency electrical power; and
- the emergency switchboard;

is not to be contiguous to the boundaries of machinery spaces of Category A or those spaces containing:

- the main source of electrical power, associated transforming equipment, if any; or
- the main switchboard.

5.2.5 Where compliance with *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.3* or *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.4* is not practicable, details of the proposed arrangements are to be submitted.

5.2.6 Provided that suitable measures are taken for safeguarding independent emergency operation under all circumstances, the emergency generator may be used, exceptionally, and for short periods, to supply non-emergency circuits.

5.2.7 The electrical power available is to be sufficient to supply all those services that are essential for safety in an emergency, due regard being paid to such services as may have to be operated simultaneously. The emergency source of electrical power is to be capable, having regard to starting currents and the transitory nature of certain loads, of supplying simultaneously at least the following services for the periods specified hereinafter or for the period specified by the Naval Administration, *see Vol 2, Pt 9, Ch 2, 5.1 General 5.1.2*, if they depend upon an electrical source for their operation:

(a) For a period of not less than three hours, emergency lighting at every lifeboat preparation station, muster and embarkation station and over the sides.

(b) For a period of not less than 18 hours, emergency lighting as detailed below unless alternative arrangements are provided by lamps having accumulator batteries within the lighting unit that are continuously charged:

  (i) in all service and accommodation alleyways, stairways and exits, personnel lift cars and personnel lift trunks;
  (ii) in the machinery spaces and main generating stations including their control positions;
  (iii) in all control stations, machinery control rooms, and at each main and emergency switchboard;
  (iv) at all stowage positions for firemen's outfits;
  (v) at the steering gear; and
  (vi) at the emergency fire pump, at the sprinkler pump, if any, and at the emergency bilge pump, if any, and at the starting positions of their motors.

(c) For a period of not less than 18 hours:

  (i) the navigation lights and other lights required by the International Regulations for Preventing Collisions at Sea in force; and
  (ii) The radiocommunications, as required by Amendments to SOLAS 1974, *Chapter IV - Radiocommunications see also Vol 2, Pt 9, Ch 2, 5.6 Radio installation* Radio installation.

(d) For a period of not less than 18 hours:

  (i) all internal communication equipment as required in an emergency;
  (ii) the navigational aids;
  (iii) the fire detection and fire-alarm system; and
  (iv) intermittent operation of the daylight signalling lamp, the ship's whistle, the manually operated call points and all internal signals that are required in an emergency, unless such services have an independent supply for the period of not less than 18 hours from an accumulator battery, suitably located for use in an emergency;

(e) For a period of 18 hours:

(i) the emergency fire pump if dependent upon the emergency source of electrical power;
(ii) the automatic sprinkler pump, if any; and
(iii) if any, the emergency bilge pump and all the equipment essential for the operation of electrically- powered remote controlled bilge valves.

(f) The steering gear for the period of time required by *Vol 2, Pt 6, Ch 1, 9 Alternative sources of power and emergency operation*

(g) For a period of half an hour:

(i) any watertight doors if electrically-operated together with their control, indication and alarm circuits;
(ii) the emergency arrangements to bring the lift cars to deck level for the escape of persons. Personnel lift cars may be brought to deck level sequentially in an emergency.

(h) Where applicable, the services required by *Vol 2, Pt 9, Ch 2, 4.3 Starting arrangements 4.3.2*

(i) Engine cooling water and lubricating oil pumps, if independently driven.

5.2.8 The emergency source of electrical power may be either a generator or an accumulator battery, which is to comply with the following:

(a) Where the emergency source of electrical power is a generator it is to be:

(i) driven by a suitable prime mover with an independent supply of fuel, having a flashpoint (closed-cup test) of not less than 43ºC;
(ii) started automatically upon failure of the main source of electrical power supply unless a transitional source of emergency electrical power in accordance with *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.9* is provided; where the emergency generator is automatically started, it is to be automatically connected to the emergency switchboard; those services referred to in *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7* are to be connected automatically to the emergency generator; and
(iii) provided with a transitional source of emergency electrical power as specified in *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.9* unless an emergency generator is provided capable both of supplying the services mentioned in that paragraph and of being automatically started and supplying the required load as quickly as is safe and practicable subject to a maximum of 45 seconds.

(b) Where the emergency source of electrical power is an accumulator battery it is to be capable of:

(i) carrying the emergency electrical load without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage;
(ii) automatically connecting to the emergency switchboard in the event of failure of the main source of electrical power;
(iii) immediately supplying at least those services specified in *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7*; and
(iv) remote control of fire extinguishing systems if electrical.

5.2.9 The transitional source of emergency electrical power where required by *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.8* is to consist of an accumulator battery suitably located for use in an emergency which is to operate without recharging while maintaining the voltage of the battery throughout the discharge period within 12 per cent above or below its nominal voltage and be of sufficient capacity and is to be so arranged as to supply automatically in the event of failure of either the main or the emergency source of electrical power at least the following services if they depend upon an electrical source for their operation:

(a) the lighting required by *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7*, *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7* and *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7*. For this transitional phase, the required emergency electric lighting, in respect of the machinery space and accommodation and service spaces may be provided by permanently fixed, individual, automatically charged, relay operated accumulator lamps; and

(b) all services required by *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7*, *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7* and *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7* unless such services have an independent supply for the period specified from an accumulator battery suitably located for use in an emergency.

(c) Power to operate the watertight doors at least three times, i.e. closed-open-closed against an adverse list of 15°, but not necessarily all of them simultaneously, together with their control, indication and alarm circuits as required by *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7*.

5.2.10 The emergency switchboard is to be installed as near as is practicable to the emergency source of electrical power.

5.2.11 Where the emergency source of electrical power is a generator, the emergency switchboard is to be located in the same space unless the operation of the emergency switchboard would thereby be impaired.

5.2.12 No accumulator battery fitted in accordance with this Section, unless for engine starting, is to be installed in the same space as the emergency switchboard. An indicator shall be mounted in a suitable place on the main switchboard or in the machinery control room to indicate when the batteries constituting either the emergency source of electrical power or the transitional source of electrical power are being discharged.

5.2.13 The emergency switchboard is to be supplied during normal operation from the main switchboard by an interconnector feeder which is to be adequately protected at the main switchboard against overload and short circuit and which is to be disconnected automatically at the emergency switchboard upon failure of the main source of electrical power. Where the system is arranged for feedback operation, the interconnector feeder is also to be protected at the emergency switchboard at least against short circuit.

5.2.14 In order to ensure ready availability of the emergency source of electrical power to supply circuits required to provide emergency services, arrangements are to be made, where necessary, to automatically disconnect non-emergency circuits from the emergency switchboard in the event of overloading to ensure that electrical power is available to the emergency circuits.

5.2.15 Provision is to be made for the periodic testing of the complete emergency system and is to include the testing of automatic starting arrangements.

5.3 Starting arrangements

5.3.1 Where the emergency source of power is a generator, the starting arrangements are to comply with the requirements given in *Vol 2, Pt 2, Ch 1, 7.3 Starting of the emergency source of power*.

5.4 Prime mover governor

5.4.1 Where the emergency source of power is a generator, the governor is to comply with *Vol 2, Pt 9, Ch 2, 4.4 Prime mover governors*.

5.5 Alternative sources of emergency electrical power

5.5.1 Where it is proposed that a dedicated emergency source of electrical power and its associated transitional source of power will not be provided, the main source of electrical power and associated equipment is to meet the requirements of *Vol 2, Pt 9, Ch 2, 5.5 Alternative sources of emergency electrical power 5.5.2*. For such installations where the Rules specify a supply from the emergency source of power, this is to be achieved by an alternative supply meeting the requirements of *Vol 2, Pt 9, Ch 2, 5.5 Alternative sources of emergency electrical power 5.5.2*.

5.5.2 The main sources of electrical power are to be

(a) separated and located in two or more compartments that are not contiguous with each other;
(b) self-contained and arranged to be independent such that each system can operate without recourse to the other main source(s) including power distribution and any associated converting equipment and control systems;
(c) arranged such that a fire or casualty in any one of the compartments will not affect the electrical power distribution from the other(s), or to the services required by *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7*.

5.5.3 The generator sets referred to in *Vol 2, Pt 9, Ch 2, 5.5 Alternative sources of emergency electrical power 5.5.2* are to be capable of being started automatically on loss of the power supplied by the other main source(s) of electrical power and supplying the services required by *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7* as quickly as is safe and practicable subject to a maximum of 45 seconds, or provided with a transitional source of emergency electrical power as specified in *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.9*.

5.5.4 The number and arrangements of generators are to allow for maintenance at sea of any one generator without affecting the ability to comply with *Vol 2, Pt 9, Ch 2, 5.5 Alternative sources of emergency electrical power 5.5.2*.

5.5.5 Starting arrangements of main sources of electrical power are to comply with the requirements of *Vol 2, Pt 2, Ch 1, 7.3 Starting of the emergency source of power*.

5.5.6 Where these Rules specify that a service is required to be connected to both the main and emergency source of electrical power or is to be connected to the emergency switchboard, then these services are to be served by at least two individual circuits from the separated main sources of electrical power with arrangements to transfer between the two sources. The supplies are to be separated in their switchboard and throughout their length as widely as is practicable without the use of

common feeders, protective devices, control circuits or controlgear assemblies, so that any single electrical fault will not cause the loss of both supplies.

5.5.7 Provision is to be made for periodic testing to demonstrate services required by *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7* can be supplied automatically following the loss of one main source of electrical power.

5.5.8 To demonstrate compliance with the requirements of *Vol 2, Pt 9, Ch 2, 5.5 Alternative sources of emergency electrical power 5.5.2*, a risk assessment of the electrical, mechanical and piping arrangements is to be carried out demonstrating that a single point failure such as a fire within a space would not render the systems incapable of supplying those services required in an emergency, *see Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*.

5.6 Radio installation

5.6.1 Every fixed radio installation is to be provided with reliable, permanently arranged electrical lighting, independent of the main and emergency sources of electrical power, for the adequate illumination of the radio controls for operating the radio installation.

5.6.2 A reserve source or sources of energy is to be provided on every ship, for the purpose of conducting distress and safety radiocommunications, in the event of failure of the ship's main and emergency sources of electrical power. The reserve source or sources of energy is to be capable of simultaneously operating the VHF radio installation and, as appropriate for the sea or sea area for which the ship is equipped, either the MF radio installation, the MF/HF radio installation, or the INMARSAT ship earth station and any of the additional loads mentioned in *Vol 2, Pt 9, Ch 2, 5.5 Alternative sources of emergency electrical power 5.5.4*, *Vol 2, Pt 9, Ch 2, 5.5 Alternative sources of emergency electrical power 5.5.6* and *Vol 2, Pt 9, Ch 2, 5.5 Alternative sources of emergency electrical power 5.5.7* for a period of at least one hour. The reserve source or sources of energy need not supply independent HF and MF radio installations at the same time.

5.6.3 The reserve source or sources of energy is to be independent of the propelling power of the ship and the ship's electrical system.

5.6.4 Where, in addition to the VHF radio installation, two or more of the other radio installations, referred to in *Vol 2, Pt 9, Ch 2, 5.5 Alternative sources of emergency electrical power 5.5.2*, can be connected to the reserve source or sources of energy, the reserve source or sources are to be capable of simultaneously supplying, for the period specified by *Vol 2, Pt 9, Ch 2, 5.6 Radio installation 5.6.2*, the VHF radio installation and:

(a) all other radio installations which can be connected to the reserve source or sources of energy at the same time; or
(b) whichever of the other radio installations will consume the most power, if only one of the other radio installations can be connected to the reserve source or sources of energy at the same time as the VHF radio installation.

5.6.5 The reserve source or sources of energy may be used to supply the electrical lighting required by *Vol 2, Pt 9, Ch 2, 5.6 Radio installation 5.6.1*

5.6.6 Where a reserve source of energy consists of a rechargeable accumulator battery or batteries a means of automatically charging the batteries is to be provided which is to be capable of recharging them to minimum capacity requirements within 10 hours.

5.6.7 If an uninterrupted input of information from the ship's navigational or other equipment to a radio installation as referred to in *Vol 2, Pt 9, Ch 2, 5.6 Radio installation 5.6.2* is needed to ensure its proper performance, means are to be provided to ensure the continuous supply of such information in the event of failure of the ship's main or emergency source of electrical power.

■ *Section 6* Generators

6.1 General requirements

6.1.1 Generators are to comply with the general requirements as specified within *Vol 2, Pt 9, Ch 3, 6.1 General requirements*.

6.1.2 The application of shaft material for main engine-driven generators where the shaft is part of the propulsion shafting is to comply with the *Rules for Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) and are to be manufactured under LR survey.

6.1.3 Generators that form part of the electrical propulsion systems are to have at least one embedded temperature detector (ETD) in each phase of the machine winding in locations which may be subjected to the highest temperature. Where there are two coil sides per slot the ETD's are to be located between the insulated coil sides in the slot, *see Vol 2, Pt 4, Ch 5, 4.1 General 4.1.4*.

6.1.4 A high bearing temperature alarm is to be provided where the generators of 100 kW and above are supplied with forced lubrication.

6.1.5 A low lubricating oil pressure alarm is to be provided for generators that are supplied with forced lubrication.

6.2 Ratings

6.2.1 For generator ratings the applicable requirements of *Vol 2, Pt 9, Ch 3, 6.2 Ratings* are to be complied with.

6.2.2 Generators are to be capable of an overload power of not less than 10 per cent at their rated power factor for a period of 15 minutes without injurious heating.

6.3 Temperature rise

6.3.1 For generator temperature rise the applicable requirements of *Vol 2, Pt 9, Ch 3, 6.3 Temperature rise* are to be complied with.

6.4 Generator control

6.4.1 Each alternating current generator, unless of the self-regulating type, is to be provided with automatic means of voltage regulation; voltage build-up is not to require an external source of power. Provision is to be made to safeguard the distribution system should there be a failure of the voltage regulating system resulting in a high voltage.

6.4.2 The voltage regulation of any alternating current generator with its regulating equipment is to be such that at all loads, from zero to full load at rated power factor, the rated voltage is maintained within ±2,5 per cent under steady conditions. There is to be provision at the voltage regulator to adjust the generator no-load voltage.

6.4.3 Generators and their excitation systems, when operating at rated speed and voltage on no-load, are to be capable of absorbing the suddenly switched, balanced, current demand of the largest motor or load at a power factor not greater than 0,4 with a transient voltage dip which does not exceed 15 per cent of rated voltage. The voltage is to recover to rated voltage within a time not exceeding 1,5 seconds. In the absence of precise data, the applied load is to be not less than 50 per cent of rated kVA at a power factor not greater than 0,4.

6.4.4 The transient voltage rise at the terminals of a generator is not to exceed 20 per cent of rated voltage when rated kVA at a power factor not greater than 0,8 is thrown off. When a generator is supplying any load between 25 per cent and 100 per cent of rated load, and a load equal to 25 per cent rated load at a power factor of 0,8 is suddenly removed, the transient voltage rise at the terminals of the generator is not to exceed 7,5 per cent.

6.4.5 Generators and their voltage regulation systems are to be capable of maintaining, without damage, under steady state short circuit conditions a current of at least three times the full load rated current for a duration of at least two seconds or where precise data is available for the duration of any time delay which may be provided by a tripping device for discrimination purposes. The generator terminal voltage is not to exceed 130 per cent of the rated voltage when the short circuit is removed.

6.4.6 Generators required to run in parallel are to be stable from no load (kW) up to the total combined full load (kW) of the group, and load sharing is to be such that the load on any generator does not normally differ from its proportionate share of the total load by more than 15 per cent of the rated output (kW) of the largest machine or 25 per cent of the rated output (kW) of the individual machine, whichever is less.

6.4.7 When generators are operated in parallel, the kVA loads of the individual generating sets are not to differ from the proportionate share of the total kVA load by more than five per cent of the rated kVA output of the largest machines.

6.4.8 For **ELS** notation, *see Vol 2, Pt 9, Ch 1, 3.2 General requirements 3.2.5*.

6.5 Overloads

6.5.1 Machines are to withstand on test, without injury, the momentary overload of an excess current of 50 per cent for 30 seconds after attaining the temperature rise corresponding to rated load, the terminal voltage being maintained as near the rated value as possible. The foregoing does not apply to the overload torque capacity of the prime mover.

6.6 Machine enclosure

6.6.1 For generator enclosures the applicable requirements of *Vol 2, Pt 9, Ch 3, 6.5 Machine enclosure* are to be complied with.

6.7 Direct current machines

6.7.1 For direct current generators the applicable requirements of *Vol 2, Pt 9, Ch 3, 6.6 Direct current machines* are to be complied with.

6.8 Survey and testing

6.8.1 For survey and testing of generators the applicable requirements of *Vol 2, Pt 9, Ch 3, 6.7 Survey and testing* are to be complied with.

■ *Section 7* Batteries

7.1 General requirements

7.1.1 The requirements of this Section apply to permanently installed secondary batteries of the vented and valve regulated sealed type.

7.1.2 A vented battery is one in which the cells have a cover provided with an opening through which the products of electrolysis and evaporation are allowed to escape freely from the cells to the atmosphere.

7.1.3 A valve-regulated sealed battery is one in which the cells are closed but have an arrangement (valve) which allows the escape of gas if the internal pressure exceeds a predetermined value. The electrolyte cannot normally be replaced.

7.2 Construction

7.2.1 Batteries are to be constructed so as to prevent spilling of the electrolyte due to motion and to minimise the emission of electrolyte spray.

7.3 Location

7.3.1 Vented batteries connected to a charging device with a power output of more than 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, are to be housed in an adequately ventilated compartment assigned to batteries only, or in an adequately ventilated suitable box on open deck.

7.3.2 Vented batteries connected to a charging device with a power output within the range 0,2 kW to 2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, are to be installed in accordance with *Vol 2, Pt 9, Ch 2, 7.3 Location 7.3.1*, or may be installed in a box within a well ventilated machinery or similar space.

7.3.3 Vented batteries connected to a charging device with a power output of less than 0,2 kW, calculated from the maximum obtainable charging current and the nominal voltage of the battery, may be installed in an open position or in a battery box in any suitable space.

7.3.4 Where more than one charging device is installed for any battery or group of batteries in one location, the total power output is to be used to determine the installation requirements of *Vol 2, Pt 9, Ch 2, 7.3 Location 7.3.1*, *Vol 2, Pt 9, Ch 2, 7.3 Location 7.3.2* or *Vol 2, Pt 9, Ch 2, 7.3 Location 7.3.3*.

7.3.5 Valve-regulated sealed batteries may be located in compartments with standard marine or industrial electrical equipment provided that the ventilation requirements of *Vol 2, Pt 9, Ch 2, 7.5 Ventilation 7.5.10*and the charging requirements of *Vol 2, Pt 9, Ch 2, 7.6 Charging facilities 7.6.4* and *Vol 2, Pt 9, Ch 2, 7.6 Charging facilities 7.6.5* are complied with. Equipment that may produce arcs, sparks or high temperatures in normal operation is not to be in close proximity to battery vent plugs or pressure relief valve outlets.

7.3.6 Where lead-acid and nickel-cadmium batteries are installed in the same compartment, precautions are to be taken, such as the provision of screens, to prevent possible contamination of electrolytes.

7.3.7 Where batteries may be exposed to the risk of mechanical damage or falling objects, they are to be suitably protected.

7.3.8 A permanent notice prohibiting naked lights and smoking is to be prominently displayed in all compartments containing vented type batteries.

7.3.9 Only electrical equipment necessary for operational reasons and for the provision of lighting is to be installed in compartments provided in compliance with *Vol 2, Pt 9, Ch 2, 7.3 Location 7.3.1*, the compartment ventilation exhaust ducts and zones within a 1,5 m radius of the ventilation outlet(s). Such electrical equipment is to be certified for group IIC gases and temperature Class T1 in accordance with the applicable parts of IEC 60079: *Explosive atmospheres,*, or an acceptable and relevant National Standard.

7.3.10 A permanent notice is to be prominently displayed adjacent to battery installations advising personnel that replacement batteries are to be of an equivalent performance type. For valve-regulated sealed batteries, the notice is to advise of the requirement for replacement batteries to be suitable with respect to products of electrolysis and evaporation being allowed to escape from cells to the atmosphere, *see also Vol 2, Pt 9, Ch 1, 1.7 Alterations and additions 1.7.6*.

7.4 Installation

7.4.1 Batteries are to be arranged such that each cell or crate of cells is accessible from the top and at least one side and it is to be ensured that they are safely secured.

7.4.2 The materials used in the construction of a battery rack or stand are to be resistant to the battery electrolyte or suitably protected by paint or a coating.

7.4.3 Measures are to be taken to minimise the effect of any electrolyte spillage and leakage, for example the use of rubber capping around the top of the cells and the provision of a tray of electrolyte-resistant material below the cells, unless the deck is suitably protected with paint or a coating.

7.4.4 The interiors of all compartments for batteries, including crates, trays, boxes, shelves and other structural parts therein, are to be of an electrolyte-resistant material or suitably protected, for example with paint or a coating.

7.5 Ventilation

7.5.1 Battery compartments and boxes are to be ventilated to avoid accumulation of dangerous concentrations of flammable gas.

7.5.2 Ducted natural ventilation may be employed for battery installations connected to a charging device with a power output of 2 kW or less, provided the exhaust duct can be run directly from the top of the compartment or box to the open air above, with no part of the duct more than 45° from the vertical. A suitable opening is also to be provided below the level of the top of the batteries, so as to ensure a free ventilation air flow. The ventilation duct is to have an area not less than 50 cm^2 for every 1 m^3 of battery compartment or box volume.

7.5.3 Where natural ventilation is impracticable or insufficient, mechanical ventilation is to be provided, with the air inlet located near the floor and the exhaust at the top of the compartment.

7.5.4 Mechanical exhaust ventilation complying with *Vol 2, Pt 9, Ch 2, 7.5 Ventilation 7.5.9* is to be provided for battery installations connected to a charging device with a total maximum power output of more than 2 kW. Also, to minimise the possibility of oxygen enrichment, compartments and spaces containing batteries with boost charging facilities are to be provided with mechanical exhaust ventilation irrespective of the charging device power output.

7.5.5 The ventilation system for battery compartments and boxes, other than boxes located on open deck or in spaces to which *Vol 2, Pt 9, Ch 2, 7.3 Location 7.3.2*, *Vol 2, Pt 9, Ch 2, 7.3 Location 7.3.3* and *Vol 2, Pt 9, Ch 2, 7.3 Location 7.3.5* refer, is to be separate from other ventilation systems. The exhaust ducting is to be led to a location in the open air, where any gases can be safely diluted, away from possible sources of ignition and openings into spaces where gases may accumulate.

7.5.6 Fan motors associated with exhaust ducts from battery compartments are to be placed external to the ducts and the compartments.

7.5.7 Ventilating fans for battery compartments are to be so constructed and be of material such as to minimise risk of sparking in the event of the impeller touching the casing. Non-metallic impellers are to be of an anti-static material.

7.5.8 Battery boxes are to be provided with sufficient ventilation openings located so as to avoid accumulation of flammable gas whilst preventing the entrance of rain or spray.

7.5.9 The ventilation arrangements for all installations of vented type batteries are to be such that the quantity of air expelled is at least equal to:

$$Q = 110\, I\, n$$

where

n = number of cells in series

I = maximum current delivered by the charging equipment during gas formation, but not less than 25 per cent of the maximum obtainable charging current in amperes

Q = quantity of air expelled in litres/hr.

7.5.10 The ventilation rate for compartments containing valve-regulated sealed batteries may be reduced to 25 per cent of that given in *Vol 2, Pt 9, Ch 2, 7.5 Ventilation 7.5.9*

7.6 Charging facilities

7.6.1 Charging facilities are to be provided for all secondary batteries such that they may be completely charged from the completely discharged state in a reasonable time having regard to the service requirements.

7.6.2 Suitable means, including an ammeter and a voltmeter, are to be provided for controlling and monitoring charging of batteries, and to protect them against discharge into the charging circuits.

7.6.3 For floating circuits or any other conditions where the load is connected to the battery whilst it is on charge, the maximum battery voltage is not to exceed the safe value for any connected apparatus.

7.6.4 Arrangements are to be fitted to automatically control the charging rate of valve regulated sealed batteries so as to prevent overcharging which may lead to an excessive evolution of gas. These arrangements are to take account of any requirements for prolonged operation under close down conditions.

7.6.5 Boost charge facilities, where provided, are to be arranged such that they are automatically disconnected should the battery compartment ventilation system fail.

7.7 Recording of batteries for emergency and essential services

7.7.1 A schedule of batteries fitted for use for Mobility systems, Ship Type systems, and emergency services is to be compiled and maintained.

7.7.2 Procedures are to be put in place and documented to ensure that, where batteries are replaced, they are of an equivalent performance type, *see also Vol 2, Pt 9, Ch 1, 1.7 Alterations and additions 1.7.6*.

7.7.3 When additions or alterations are proposed to the existing batteries for Mobility systems, Ship Type systems, and emergency services, the schedule and replacement procedure documentation are to be updated to reflect the proposed installation and submitted in accordance with *Vol 2, Pt 9, Ch 1, 1.7 Alterations and additions 1.7.1*.

7.7.4 The schedule and replacement procedure documentation are to be made available to the LR Surveyor on request.

■ *Section 8* External source of electrical power

8.1 Temporary external supply

8.1.1 Where arrangements are made for the supply of electricity from a source on shore or elsewhere, a connection box is to be installed in a position suitable for the convenient reception of flexible cables from the external source and containing fuses and terminals including one earthed, of ample size and suitable shape to facilitate an appropriate supply.

8.1.2 Suitable cables, permanently fixed, are to be provided, connecting the terminals in the connection box to a linked switch and/or a circuit-breaker at the main switchboard. An indicator is to be provided at the main switchboard in order to show when the cables are energised.

8.1.3 Means are to be provided for checking the phase sequence of the incoming supply.

8.1.4 At the connection box a notice is to be provided giving full information on the system of supply, the normal voltage and frequency of the installation's system and the procedure for carrying out the connection.

8.1.5 Alternative arrangements may be submitted for consideration.

■ *Section 9*
Other sources of electrical power

9.1 General

9.1.1 Other sources of power and storage devices not covered by the Sections above are to be subject to special considerations and are to satisfy the requirements of *Vol 2, Pt 5, Ch 1 Torsional Vibration*.

Electrical Power Distribution and Equipment

Section

■ Scope

The requirements of this Chapter are applicable to the design and construction philosophy of electrical distribution system and connected consumers.

This Chapter details the requirements for sub-systems and equipment within the boundary of electrical power distribution and are applicable for main and emergency auxiliary power systems as well as integrated electrical power generation and propulsion systems.

Application of this Chapter will facilitate the verification of the performance requirements of *ANEP -77 NATO Naval Ship Code*, Chapter IV, Regulation 10.

■ *Section 1* Functional requirements

1.1 Functional requirements

1.1.1 Electrical power shall be safely distributed to consumers throughout the vessel.

■ *Section 2* Performance requirements

2.1 Performance requirements

2.1.1 Electrical equipment is to be suitable for the quality of electrical power supply encountered on board.

2.1.2 Electrical equipment and distribution systems are to meet the requirements of *Vol 2, Pt 9, Ch 4 Electrical Protection*.

2.1.3 The electrical system voltages and frequencies shall be selected to ensure safe provision of electrical power to systems and to minimise the risk of exposure to personnel.

2.1.4 The design of the type and configuration of the distribution system is to consider earthing arrangements to minimise the risk to personnel and equipment under normal and foreseeable abnormal conditions.

2.1.5 The number, size, installation and arrangement of electrical switchboards and distribution centres shall be suitable for the functional requirements of the vessel.

2.1.6 The design of the electrical distribution system is to ensure that a single point of failure will not result in unavailability of both main and emergency sources of electrical power.

2.1.7 Cables shall be installed such that risk of injury to personnel or damage to the system is minimised when equipment is operating in foreseeable conditions or under reasonable foreseeable abnormal conditions.

2.1.8 Where a single consumer requires a main and emergency supply of electrical power, they shall be separated as widely as is practicable.

2.1.9 The continuity of supply to services that are essential for safety in an emergency shall be ensured under all normal and reasonably foreseeable abnormal conditions.

2.1.10 The continuity of supply to Mobility and/or Ship Type systems is to be ensured under normal operation and defined abnormal conditions.

2.1.11 Suitable arrangements for the isolation and switching of distribution circuits shall be provided.

2.1.12 Installation of cables shall not cause mutual interference between systems.

2.1.13 A means to detect insulation breakdown with respect to earth within equipment and distribution systems and to alert the Operator shall be provided.

2.1.14 Cables shall be installed such that risk of injury to personnel or damage to the system is minimised when equipment is operating in foreseeable or under fault conditions.

2.1.15 Exposed metal parts of electrical machines or equipment which are not intended to be live but which may become live under fault conditions shall be earthed.

2.1.16 Essential safety functions shall be supplied using fire-resistant cable.

2.1.17 Electrical equipment and distribution systems shall be suitably protected from mechanical damage.

2.1.18 Alternative arrangements for cooling of Mobility and/or Ship Type systems in the event of a forced cooling system failure shall be provided.

2.1.19 Personnel, equipment and platform are to be protected from the risk of static electricity.

■ *Section 3*
Verification requirements

3.1 General

3.1.1 Compliance with the requirements in *Vol 2, Pt 9, Ch 3, 4 Supply and distribution* inclusive is deemed to satisfy the functional requirements and performance requirements above.

3.1.2 Where a designer offers a novel solution, an engineering safety and justification report is to be submitted. The engineering safety and justification report is to demonstrate how the proposed solution will satisfy the functional requirements and performance requirements in *Vol 2, Pt 9, Ch 3, 1 Functional requirements* and *Vol 2, Pt 9, Ch 3, 2 Performance requirements*.

3.1.3 The Naval Administration may impose requirements additional to those in this Chapter.

■ *Section 4* Supply and distribution

4.1 Systems of supply and distribution

4.1.1 The following systems of generation and distribution are acceptable:

(a) d.c., two-wire;
(b) a.c., single-phase, two-wire;
(c) a.c., three-phase:
    (i) three-wire insulated;
    (ii) three-wire with neutral solidly earthed or earthed through an impedance;
    (iii) four-wire with neutral solidly earthed but without hull return.

Note Where the **ELS** notation is to be assigned, earthed systems are permitted only when the additional requirements of *Vol 2, Pt 9, Ch 3, 4.5 Earthed distribution systems 4.5.7* are satisfied. *See also Vol 2, Pt 9, Ch 1, 3.2 General requirements 3.2.3*.

4.1.2 For oil supply ships intended for the carriage in bulk of oil and other hazardous liquids having a flash point not exceeding 60°C (closed-cup test) only the following systems of generation and distribution are acceptable:

(a) d.c., two-wire insulated;
(b) a.c., single-phase, two-wire, insulated;
(c) a.c., three-phase, three-wire, insulated;
(d) earthed systems, a.c. or d.c., limited to areas outside any dangerous space or zone, and arranged so that no current arising from an earth-fault in any part of the system could pass through a dangerous space or zone. Earthed intrinsically safe circuits are permitted to pass into and through dangerous spaces and zones.

4.1.3 System voltages for both alternating current and direct current in general are not to exceed:

15 000 V for generation and power distribution;

500 V for cooking and heating equipment permanently connected to fixed wiring;

250 V for lighting, heaters in cabins and crew and embarked personnel rooms, and other applications not mentioned above.

Voltages above these will be the subject of special consideration.

4.1.4 The arrangement of the main system of supply is to be such that a fire or other casualty in a space containing any of the main sources of electrical power will not render inoperable any of the other main sources of electrical power, or any emergency supply system if fitted.

4.1.5 Main switchboards, lighting distribution boards and any converting equipment are to be so placed relative to their associated generator(s) so that, as far as is practicable, the integrity of the main system(s) of supply will be affected only by a fire or other casualty in one space. Switchboards are to be located as close as practicable to their associated generators.

4.1.6 The arrangement of the emergency system of supply, where fitted, is to be such that a fire or other casualty in spaces containing the emergency source of electrical power, associated converting equipment, if any, the emergency switchboard and the emergency lighting switchboard, will not cause loss of services required to maintain the propulsion and safety of the ship.

4.1.7 Distribution systems are to be so arranged that a fire in any one main fire zone will not interfere with either the main or emergency distribution systems and services in any other such zone.

4.2 Essential services

4.2.1 Mobility or Ship Type systems that are required to be duplicated are to be served by individual circuits, separated in their switchboard or section board and throughout their length as widely as is practicable without the use of common feeders, protective devices, control circuits or controlgear assemblies, so that any single fault will not cause the loss of both services.

4.2.2 Where *Vol 2, Pt 9, Ch 3, 4.2 Essential services 4.2.1* is applicable the main busbars of the switchboard, or section boards, are to be capable of being split, by a multi-pole linked circuit breaker, disconnector or switch-disconnector, into at least

two independent sections, each supplied by at least one generator, either directly or through a converter. The Mobility and/or Ship Type systems are to be equally divided, as far as is practicable, between the independent sections.

4.2.3 Where *Vol 2, Pt 9, Ch 3, 4.2 Essential services 4.2.2* is applicable provision is to be made to transfer to a temporary circuit those Mobility and/or Ship Type systems which are not required to be, and have not been, duplicated in the event of loss of their normal section of switchboard or section-board.

4.2.4 A Risk Based Assessment (RA) is to be carried out in accordance with the requirements of *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*. The RA is to verify the availability of electrical power to Mobility and/or Ship Type systems (*see Vol 2, Pt 1, Ch 1, 3.1 Categories 3.1.5*) in the event of a failure in the power supply and distribution system. The RA is to address the different system operating modes and configurations. The RA should include relevant mechanical failures which may have significant effects on the electrical power and distribution system, i.e. prime mover failures causing loss of electrical power supplies to Mobility and/or Ship Type systems. An analysis carried out by applying the relevant generic failure modes listed in IEC 60812:1985, *Analysis techniques for system reliability - Procedure for failure mode and effects analysis (FMEA)* to the system and equipment identified in the single line diagram of the electrical system (*see Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.4*) would generally be acceptable.

4.3 Isolation and switching

4.3.1 The incoming and outgoing circuits from every switchboard or section board are to be provided with a means of isolation and switching to permit each circuit to be switched off:

(a) on load;
(b) for mechanical maintenance;
(c) in an emergency to prevent or remove danger.

In addition, the requirements of *Vol 2, Pt 9, Ch 3, 4.3 Isolation and switching 4.3.2* and *Vol 2, Pt 9, Ch 3, 4.3 Isolation and switching 4.3.3* are to be complied with.

4.3.2 Isolation and switching is to be by means of a circuit breaker or switch arranged to open and close simultaneously all insulated poles. Where a switch is used as the means of isolation and switching, it is to be capable of:

(a) switching off the circuit on load;
(b) withstanding, without damage, the overcurrents which may arise during overloads and short circuit. In addition, these requirements do not preclude the provision of single pole control switches in final sub-circuits, for example light switches.

For circuit breakers, *see Vol 2, Pt 9, Ch 3, 5.3 Circuit-breakers* and *Vol 2, Pt 9, Ch 4, 4.5 Circuit-breakers*.

4.3.3 Provision is to be made, in accordance with one of the following, to prevent any circuit being inadvertently energised:

(a) the circuit breaker or switch can be withdrawn, or locked in the open position;
(b) the operating handle of the circuit breaker or switch can be removed;
(c) the circuit fuses, where fitted, can be readily removed and retained by authorised personnel.

4.3.4 Where a section board, distribution board or item of equipment can be supplied by more than one circuit, a switching device is to be provided to permit each incoming circuit to be isolated and the supply transferred to the alternative circuit. In addition, the requirements of *Vol 2, Pt 9, Ch 3, 4.3 Isolation and switching 4.3.5* and *Vol 2, Pt 9, Ch 3, 4.3 Isolation and switching 4.3.6* are to be complied with.

4.3.5 The switching device required by *Vol 2, Pt 9, Ch 3, 4.3 Isolation and switching 4.3.4* is to be situated within or adjacent to the section board, distribution board or item of equipment. Where necessary, interlocking arrangements are to be provided to prevent circuits being inadvertently energised.

4.3.6 A notice is to be fixed to any section board, distribution board or item of equipment to which *Vol 2, Pt 9, Ch 3, 4.3 Isolation and switching 4.3.4* applies warning personnel before gaining access to live parts of the need to open the appropriate circuit breakers or switches, unless an interlocking arrangement is provided so that all circuits concerned are isolated before access is gained.

4.3.7 Where high voltage equipment is contained in a room, or protected area, which also forms its enclosure, the access door(s) is (are) to be so interlocked that it (they) cannot be opened until the high voltage supply(ies) to the equipment is (are) switched off. Provision is also to be made to enable the equipment and its cable(s) to be earthed down and any stored energy dissipated, sufficient to ensure personnel safety.

4.3.8 The access to the space(s) described in *Vol 2, Pt 9, Ch 3, 4.3 Isolation and switching 4.3.7* is to be suitably marked to indicate the danger of high voltage.

4.4 Insulated distribution systems

4.4.1 A device(s) is (are) to be installed for every insulated distribution system, whether primary or secondary, for power, heating and lighting circuits, to continuously monitor the insulation level to earth and to operate an alarm in the engine control room, or equivalent attended position, in the event of an abnormally low level of insulation resistance.

4.4.2 Where any insulated lower voltage system is supplied through transformers from a high voltage system, adequate precautions are to be taken to prevent the low voltage system being charged by capacitive leakage from the high voltage system.

4.4.3 Where filters are fitted, for example to reduce EMC susceptibility, these are not to cause distribution systems to be unintentionally connected to earth.

4.5 Earthed distribution systems

4.5.1 No fuse, non-linked switch or non-linked circuitbreaker is to be inserted in an earthed conductor. Any switch or circuit-breaker fitted is to operate simultaneously in the earthed conductor and the insulated conductors. These requirements do not preclude the provision (for test purposes) of an isolating link to be used only when the other conductors are isolated.

4.5.2 For high voltage systems, where the earthed neutral system of generation and primary distribution is used, earthing is to be through an impedance in order to limit the total earth fault current to a magnitude which does not exceed that of the three phase short-circuit current for which the generators are designed.

4.5.3 Generator neutrals may be connected in common, provided that the third harmonic content of the voltage waveform of each generator does not exceed five per cent.

4.5.4 Where a switchboard is split into sections operated independently or where there are separate switchboards, neutral earthing is to be provided for each section or for each switchboard. Means are to be provided to ensure that the earth connection is not removed when generators are isolated.

4.5.5 A means of isolation is to be fitted in the earthing connection of each generator so that generators can be completely isolated for maintenance.

4.5.6 All earthing impedances are to be connected to the hull. The connections to the hull are to be so arranged that any circulating currents in the earth connections do not interfere with radio, radar, communication and control equipment circuits.

4.5.7 Where the **ELS** notation is to be assigned, earthed systems are not permitted unless they are isolated from the main generation and distribution system, e.g. through transformers and/or motor generator sets. *See also Vol 2, Pt 9, Ch 1, 3.2 General requirements 3.2.3*.

4.6 Diversity factor

4.6.1 Circuits supplying two or more final sub-circuits are to be rated in accordance with the total connected load subject, where justified, to the application of a diversity factor. Where spare ways are provided on a section or distribution board, an allowance for future increase of load is to be added to the total connected load before application of any diversity factor.

4.6.2 A diversity factor may be applied to the calculation for size of cable and rating of switchgear and fusegear, taking into account the duty cycle of the connected loads and the frequency and duration of any motor starting loads.

4.7 Lighting circuits

4.7.1 Lighting circuits are to comply with the requirements of *Vol 2, Pt 9, Ch 6 Lighting*.

4.8 Motor circuits

4.8.1 A separate final sub-circuit is to be provided for every motor for Mobility and/or Ship Type systems, *see Vol 2, Pt 1, Ch 1, 3.1 Categories 3.1.5*

4.9 Motor control

4.9.1 Every electric motor is to be provided with efficient means for starting and stopping so placed as to be easily operated by the person controlling the motor. Every motor above 0,5 kW is to be provided with control apparatus as given in *Vol 2, Pt 9, Ch 3, 4.9 Motor control 4.9.2* to *Vol 2, Pt 9, Ch 3, 4.9 Motor control 4.9.4*.

4.9.2 Means to prevent undesired restarting after a stoppage due to low volts or complete loss of volts are to be provided. This does not apply to motors where a dangerous condition might result from the failure to restart automatically, e.g. steering gear motor.

4.9.3 Means for automatic disconnection of the supply in the event of excess current due to mechanical overloading of the motor are to be provided, *see also Vol 2, Pt 9, Ch 4, 4.11 Motor circuits*

4.9.4 Motor controlgear is to be suitable for the starting current and for the full load rated current of the motor.

■ *Section 5*
Switchgear and controlgear assemblies

5.1 General requirements

5.1.1 Switchgear and controlgear assemblies and their components are to comply with the following standards as appropriate for the nominal voltage, and amended where necessary for ambient temperature and other environmental conditions:

(a) IEC 61439: *Low-voltage switchgear and controlgear assemblies (relevant parts);*
(b) IEC 62271-200: *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV;*
(c) IEC 62271-201: *High-voltage switchgear and controlgear – Part 201: AC insulation-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV*;
(d) IEC 60092-503: *Electrical installations in ships – Part 503: Special features – AC supply systems with voltages in the range of above 1 kV up to and including 15 kV*;
(e) IEC 60255: *Measuring relays and protection equipment;* or;
(f) an acceptable and relevant National Standard.

In addition, the requirements of *Vol 2, Pt 9, Ch 3, 5.2 Busbars* are to be complied with.

5.2 Busbars

5.2.1 Busbars and their connections are to be of copper or aluminium, all connections being so made as to inhibit corrosion/ oxidisation between current-carrying mating faces, which may result in poor electrical contact giving rise to overheating. Busbars and their supports are to be designed to withstand the mechanical stresses which may arise during short-circuits. A test report or calculation to verify the shortcircuit withstand strength of the busbar system is to be submitted for consideration when required.

5.2.2 For bare conductors, where no precautions are taken against surface oxidisation, the temperature rise limit at rated normal current is not to exceed 45ºC. Where suitable precautions are taken against surface oxidisation, e.g. by using silver, nickel or tin coated terminations, a temperature rise limit not exceeding 60ºC may be permitted. Where the busbar temperature rises are above 45ºC it is to be ensured that there is no adverse effect on equipment adjacent to and/or connected to the busbars and that the temperature rise limits of any materials in contact with the busbars are not exceeded. A test report or calculation to verify the rated current assigned to the busbar system is to be submitted for consideration when required.

5.3 Circuit-breakers

5.3.1 Circuit-breakers are to comply with one of the following standards amended where necessary for ambient temperature:

(a) IEC 60947-2: Low voltage switchgear and controlgear Part 2: circuit breakers; or
(b) IEC 62271-100: *High-voltage switchgear and controlgear – Part 100*: *Alternating current circuit-breakers* ;
(c) an acceptable and relevant National Standard.

Type test reports to verify the characteristics of a circuitbreaker are to be submitted for consideration when required.

5.3.2 Circuit-breakers are to be capable of isolation.

5.3.3 Circuit-breakers are to be of the trip free type and, where applicable, be fitted with anti-pumping control.

5.3.4 High-voltage circuit-breakers are to be of the withdrawable type or with equivalent means or arrangements permitting safe maintenance whilst the busbars are live.

5.3.5 Where the means of setting adjustable protection characteristics are not durably marked and locked in position and cannot be visually inspected (e.g. electronic storage), the setting of characteristics is to be recorded in accordance with an acceptable quality management system with a copy of the records included in the details retained on board, *see Vol 2, Pt 9, Ch 4, 4.1 General 4.1.4*.

5.3.6 Air circuit-breakers for Mobility systems, Ship Type systems, or emergency services and rated at 800 A and above are to have a cumulative count kept of the switching operations of the electrical contacts. This count, along with the manufacturer's details for the circuit-breaker, including the maximum number of switching operations for the electrical contacts, is to be retained on board. These details are to be made available to the Surveyor on request.

5.4 Contactors

5.4.1 High-voltage contactors are to comply with one of the following standards amended where necessary for ambient temperature:

(a) *IEC 62271-106: High-voltage switchgear and controlgear – Part 106: Alternating current contactors, contactor-based controllers and motor-starters*; or
(b) an acceptable and relevant National Standard.

Type test reports to verify the characteristics of a contactor are to be submitted for consideration when required.

5.4.2 High-voltage contactors are to be of the withdrawable type or with equivalent means or arrangements permitting safe maintenance whilst the busbars are live.

5.5 Fuses

5.5.1 Fuses are to comply with one of the following standards, amended where necessary for ambient temperature:

(a) IEC 60269 *(all parts): Low-voltage fuses*;
(b) IEC 60282-1: *High-voltage fuses – Part 1: Current-limiting fuses*; or
(c) an acceptable and relevant National Standard for enclosed current-limiting fuses.

Type test reports to verify the characteristics of a fuse are to be submitted for consideration when required.

5.6 Disconnectors and switch-disconnectors

5.6.1 Disconnectors, switch-disconnectors are to comply with one of the following standards, amended as necessary for ambient temperature and other environmental conditions:

(a) IEC 600947-3: *Low-voltage switchgear and controlgear – Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units*
(b) IEC 62271-102: *High-voltage switchgear and controlgear – Pt 102*: *High-voltage alternating current disconnectors and earthing switches*; or
(c) an acceptable and relevant National Standard.

Type test reports to verify the characteristics of a disconnector or switch-disconnector are to be submitted for consideration when required.

5.7 Creepage and clearance distances

5.7.1 The shortest distances between conductive parts and between conductive parts and earth, in air or along the surface of an insulating material, are to be suitable for the rated voltage, having regard to:

- the nature of the insulating material;
- the transient over-voltages developed by switching and fault conditions; and
- the environment into which the assembly will be installed.

Each assembly type is to be subjected to an impulse voltage test in accordance with its constructional Standard or, alternatively, the minimum distances for bare conductive parts in switchgear and controlgear assemblies given in *Table 3.5.1 Minimum clearance distances* are to be used.

Table 3.5.1 Minimum clearance distances

Nominal Voltage (V)	Minimum clearance distance (mm)		
	Verified assemblies (*See* Note 2)		Non-verified assemblies
	Main switchboards	Other switchgear and controlgear	Main switchboards and other switch and controlgear
≤250 (*See* Note 1)	8	8	15
≤690 (*See* Note 1)	8	8	20
≤1000 (*See* Note 1)	8	8	25
<3 300	32	26	55
<6 600	60	50	90
<11 000	100	80	120
≤15 000	*See* note 3	*See* note 3	160

Note 1. For assemblies installed in spaces where the pollution degree is > 3, *see Vol 2, Pt 9, Ch 3, 5.7 Creepage and clearance distances 5.7.2*.

Note 2. For the verification requirements for a verified assembly refer to IEC 61439-2.

Note 3. Clearance distances with reference to the applicable relevant National or International Standards are to be submitted for approval, *see Vol 2, Pt 9, Ch 1, 1.5 Documentation required for supporting evidence 1.5.3*.

5.7.2 For assemblies with a rated voltage of up to and including 1kV, the requirement of *Vol 2, Pt 9, Ch 3, 5.7 Creepage and clearance distances 5.7.1* may be met by complying with IEC 60092-302: *Electrical installations in ships – Part 302: Low-voltage switchgear and controlgear assemblies*:

(a) *Table 3.5.1 Minimum clearance distances* and *Table 3.5.2 Minimum creepage distance* indicate the minimum clearance and creepage distances normally allowed.

(b) For assemblies installed in spaces where the environmental conditions are in excess of pollution degree 3 (that is, conductive pollution occurs or dry, non-conductive pollution occurs which is expected to be conductive due to condensation) as defined in IEC 61439-1, *Low-voltage switchgear and controlgear assemblies – Part 1: General requirements; the clearance distances for non-verified assemblies* are to be used.

(c) A minimum creepage distance of 16 mm is permitted for assemblies verified in accordance with the requirements of IEC 61439-2, *Low-voltage switchgear and controlgear assemblies – Part 2: Power switchgear and controlgear assemblies*.

(d) An alternative relevant National or International Standard may be used when an acceptable justification is submitted as part of the documentation required by *Vol 2, Pt 9, Ch 1, 1.5 Documentation required for supporting evidence 1.5.3*.

Table 3.5.2 Minimum creepage distance

Nominal Voltage (V)	Minimum creepage distance (mm)	
	Main switchboards	Other switchgear and controlgear
≤250 (*See* Note 1)	20	20
≤690 (*See* Note 1)	25	25

≤1000 (*See* Note 1)	35	35
<3 300	48	*See* note 2
<6 600	90	70
<11 000	150	120
≤15 000	*See* note 2	*See* note 2

Note 1. For verified assemblies a minimum creepage distance of 16 mm is permitted for LV switchboards, *see Vol 2, Pt 9, Ch 3, 5.7 Creepage and clearance distances 5.7.2*.

Note 2. Creepage distances, with reference to the applicable relevant National or International Standards, are to be submitted for approval, *see Vol 2, Pt 9, Ch 1, 1.5 Documentation required for supporting evidence 1.5.3*.

5.7.3 For assemblies with a rated voltage above 1kV, the requirement of *Vol 2, Pt 9, Ch 3, 5.7 Creepage and clearance distances 5.7.1* may be met by complying with IEC 60092-503: *Electrical installations in ships – Part 503: Special features – AC supply systems with voltages in the range of above 1 kV up to and including 15 kV*.

(a) *Table 3.5.1 Minimum clearance distances* and *Table 3.5.2 Minimum creepage distance* indicate the minimum clearance and creepage distances normally allowed.
(b) For main switchboards rated at above 1kV, a minimum clearance distance of 25 mm is required for busbars and other bare conductors.
(c) An alternative relevant National or International Standard may be used when an acceptable justification is submitted as part of the documentation required by *Vol 2, Pt 9, Ch 1, 1.5 Documentation required for supporting evidence 1.5.3*.

5.7.4 Suitable shrouding or barriers are to be provided in way of connections to equipment, where necessary, to maintain the minimum distances in *Table 3.5.1 Minimum clearance distances*.

5.8 Degree of protections

5.8.1 Low voltage assemblies where the rated voltage between conductors or to earth exceeds 55 V a.c. or 250 V d.c. are to be of the deadfront or enclosed type. High-voltage assemblies are to be of the enclosed type.

5.8.2 Where switchboards or section boards are required to comply with *Vol 2, Pt 9, Ch 3, 4.2 Essential services 4.2.2*, barriers are to be installed to provide protection for the independent sections against contamination due to the products of arcing, which may result in a fault.

5.8.3 Segregation between low-voltage and high-voltage circuits and equipment installed within common assemblies is to be in accordance with IEC 62271-1: *High-voltage switchgear and controlgear – Part 1: Common specifications*.

5.9 Distribution boards

5.9.1 Distribution boards are to be suitably enclosed unless they are installed in a cupboard or compartment to which only authorised persons have access in which case the cupboard may serve as an enclosure, *see Vol 2, Pt 9, Ch 3, 5.17 Position of switchboards 5.17.4*

5.10 Earthing of high-voltage switchboards

5.10.1 High-voltage switchboards are to be provided with suitable means to earth isolated circuits so that they are discharged and so maintained that they are safe to touch.

5.10.2 Protective shutters associated with withdrawable parts are to be clearly marked, e.g. by colour coding, to indicate the incoming and outgoing circuits and bus tie connections. The colour coding shall be as follows:

- Incoming (busbar side) – red;
- Outgoing (circuit side) – yellow; and
- Bus ties – red.

5.11 Handrails or handles

5.11.1 All main and emergency switchboards are to be provided with an insulated handrail or insulated handles suitably fitted on the front of the switchboard. Where access to the rear is required, a horizontal insulated handrail is to be suitably fitted on the rear of the switchboard.

5.12 Instruments for alternating current generators

5.12.1 For alternating current generators not operated in parallel, each generator is to be provided with at least one volt-meter, one frequency meter, and one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase. Generators above 50 kVA are also to be provided with a wattmeter.

5.12.2 For alternating current generators operated in parallel, each generator is to be provided with a wattmeter, and one ammeter with an ammeter switch to enable the current in each phase to be read, or an ammeter in each phase.

5.12.3 For paralleling purposes, two voltmeters, two frequency meters and two synchronising devices are to be provided. One voltmeter and one frequency meter are to be connected to the busbars, the other voltmeter and frequency meter are to be switched to enable the voltage and frequency of any generator to be measured. Where the electrical power requirement to maintain the ship in a normal operational and habitable condition is usually supplied by two or more generators operating in parallel, the two synchronising devices are to be independent of each other, *see also Vol 2, Pt 9, Ch 2, 4.2 Number and rating of generators and converting equipment 4.2.1*.

5.12.4 The indicators and displays required by *Vol 2, Pt 9, Ch 3, 5.12 Instruments for alternating current generators 5.12.1* are to be located and arranged such that they are viewed at a single operating position. Where manual paralleling is provided, it is to be possible to adjust voltage and frequency at this position. Generators are to have controls to adjust their voltage and frequency located at the single operating position. Access to voltage adjustment is to be restricted, such that it will generally only be used by authorised personnel to avoid accidental operation.

5.12.5 Where the indications of voltage, frequency, current and power are displayed digitally, the indications are to be separately displayed.

5.13 Instrument scales

5.13.1 The upper limit of the scale of every voltmeter is to be approximately 120 per cent of the nominal voltage of the circuit, and the nominal voltage is to be clearly indicated.

5.13.2 The upper limit of the scale of every ammeter is to be approximately 130 per cent of the normal rating of the circuit in which it is installed. Normal full load is to be clearly indicated.

5.13.3 Kilowatt meters for use with alternating current generators which may be operated in parallel are to be capable of indicating 15 per cent reverse power.

5.13.4 Where the indications provided by the instrumentation required by *Vol 2, Pt 9, Ch 3, 5.12 Instruments for alternating current generators* are displayed digitally, nominal voltage, over voltage, over current and reverse power indications are to be indicated by an appropriate means. The information provided is to be clearly visible and immediately available.

5.13.5 In general, indications provided by instrumentation which are displayed digitally are not to change more frequently than twice per second.

5.14 Labels

5.14.1 The identification of individual circuits and their devices is to be made on labels of durable material. The ratings of fuses and settings of protective devices are also to be indicated. Section and distribution boards are to be marked with the rated voltage.

5.15 Protection

5.15.1 *See Vol 2, Pt 9, Ch 4, 4 System design - protection*.

5.16 Wiring

5.16.1 Insulated wiring connecting components are to be stranded, flame retardant and manufactured in accordance with a relevant and acceptable National Standard.

5.17 Position of switchboards

5.17.1 An unobstructed space not less than 1 m wide is to be provided in front of switchboards and section boards. When switchboards and section boards contain withdrawable equipment the unobstructed space is to be not less than 0,4 m wide with this equipment in its fully withdrawn position.

5.17.2 Where necessary, the space at the rear of switchboards and section boards is to be ample to permit maintenance and in general not less than 0,6 m except that this may be reduced to 0,5 m in way of stiffeners or frames.

5.17.3 The spaces defined in *Vol 2, Pt 9, Ch 3, 5.17 Position of switchboards 5.17.1* and *Vol 2, Pt 9, Ch 3, 5.17 Position of switchboards 5.17.2* are to have non-slip surfaces. Where access to live parts within switchboards and section boards is normally possible the surface is, in addition, to be electrically insulated.

5.17.4 So far as is practicable, pipes are not to be installed directly above or in front of or behind switchboards, section boards and distribution boards. If such placing is unavoidable, suitable protection is to be provided in these positions. *See Vol 2, Pt 7, Ch 2, 2.8 Miscellaneous requirements*

5.17.5 For switchgear and controlgear assemblies, for rated voltages above 1 kV, arrangements are to be made to protect personnel in the event of gases or vapours escaping under pressure as the result of arcing due to an internal fault. Where personnel may be in the vicinity of the equipment when it is energised, this may be achieved by an assembly that has been tested in accordance with Annex A of IEC 62271- 200: 2011: *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV* and qualified for classification **IAC** (internal arc classification).

5.18 Switchboard auxiliary power supplies

5.18.1 Where the operation of a protective device relies upon a power supply, an alarm is to be provided to indicate failure of the power supply, unless its failure causes automatic tripping of the protected circuit.

5.19 Testing

5.19.1 Tests in accordance with *Vol 2, Pt 9, Ch 3, 5.19 Testing 5.19.2* are to be satisfactorily carried out on all assemblies, complete or in sections, at the manufacturer's premises, and a test report issued by the manufacturer, *see also Vol 2, Pt 9, Ch 1, 1.6 Surveys 1.6.2*.

5.19.2 A high voltage test, *see Vol 2, Pt 9, Ch 11, 1 Testing and trials*.

5.19.3 Calibration of protective devices and indicating instruments is to be verified by means of current and/or voltage injection.

5.19.4 Demonstration of the satisfactory operation of protection circuits, control circuits and interlocks by means of simulated functional tests.

5.19.5 For switchgear and controlgear assemblies, for rated voltages above 1 kV, type tests are to be carried out, in accordance with Annex A of IEC 62271-200: 2011: *High-voltage switchgear and controlgear – Part 200: AC metal-enclosed switchgear and controlgear for rated voltages above 1 kV and up to and including 52 kV* and **IAC** (internal arc classification) assigned, to verify that the assembly will withstand the effects of an internal arc occurring within the enclosure at a prospective fault level equal to, or in excess of, that of the installation.

■ *Section 6* Rotating machines – general requirements and motors

6.1 General requirements

6.1.1 Rotating machines are to comply with the relevant part of IEC 60092, or an acceptable and relevant National Standard, and the requirements of this section. In addition, military aspects for shock are to be defined as required by *Vol 2, Pt 1, Ch 3, 4.9 Military requirements*.

6.1.2 For all the rotating machines a manufacturer's test certificate is to be provided, *see also Vol 2, Pt 9, Ch 3, 6.7 Survey and testing*.

6.1.3 All machines of 100 kW and over, intended for Mobility or Ship Type systems, are to be surveyed by the Surveyor during manufacture and test.

6.1.4 Shaft materials for rotating machines for Mobility or Ship Type systems are to comply with the *Rules for Manufacture, Testing and Certification of Materials* (hereinafter referred to as the Rules for Materials) and are to be manufactured under LR survey for the following applications:

(a) shaft material for dynamic positioning and electric propulsion motors; and
(b) shaft material for machines with power ratings of 250 kW or greater.

Shaft material for machines with power ratings less than 250 kW is to have a manufacturer's certificate as detailed in *Ch 1 General Requirements* of the Rules for Materials.

6.1.5 Where welding is applied to shafts of machines for securing arms or spiders, stress relieving is to be carried out after welding. The finalised assembly is to be visually examined by the Surveyors, crack detection carried out by an appropriate method and the finished welds found sound and free from cracks.

6.1.6 The rotating parts of machines are to be so balanced that when running at any speed in the normal working range the vibration does not exceed the levels of IEC 60034-14: *Rotating electrical machines – Part 14: Mechanical vibration of certain machines with shaft heights 56 mm and higher – Measurement, evaluation and limits of vibration severity.*

6.1.7 The lubrication arrangement for bearings are to be effective under all operating conditions including the maximum ship inclinations defined by *Table 3.4.2 Inclinations*, *Vol 2, Pt 1, Ch 3, 4.6 Inclination of ship* and there are to be effective means provided to ensure that lubricant does not reach the machine windings or other conductors and insulators.

6.1.8 Means are to be taken to prevent the ill effects of the flow of currents circulating between the shaft and machine bearings or bearings of connected machinery.

6.1.9 Alternating current machines are to be constructed such that, under any operating conditions, they are capable of withstanding the effects of a sudden short circuit at their terminals without damage.

6.1.10 For high voltage machines, the stator insulation system is to be of a type that has undergone sample testing in accordance with the following International Standards, or relevant alternatives acceptable to LR, to demonstrate its suitability for the operating voltage in the presence of an LR Surveyor:

(a) *IEC 60894, Guide for a test procedure for the measurement of loss tangent of coils and bars for machine windings*, at the insulation class rated temperature; and
(b) *IEC 60034-15, Impulse Voltage Withstand Levels of Form-wound Stator Coils for Rotating a.c. Machines*, with power-frequency voltage withstand testing conducted.

Test samples are to be representative in terms of the number and size of conductors, coil construction, combination of materials and manufacturing process

6.1.11 For testing required by *Vol 2, Pt 9, Ch 3, 6.1 General requirements 6.1.10* on coils relating to global vacuum pressure impregnated systems, test samples representing the unimpregnated state and the impregnated state of the final winding and stator core are to be used as appropriate for testing.

6.2 Ratings

6.2.1 Generators, including their excitation systems, and continuously rated motors are to be suitable for continuous duty at their full rated output at maximum cooling air or water temperature for an unlimited period, without the limits of temperature rise in *Vol 2, Pt 9, Ch 3, 6.3 Temperature rise* being exceeded. Generators are to be capable of an overload power of not less than 10 per cent at their rated power factor for a period of 15 minutes without injurious heating. Other machines are to be rated in accordance with the duty which they have to perform and, when tested under rated load conditions, the temperature rise is not to exceed the values in *Vol 2, Pt 9, Ch 3, 6.3 Temperature rise*

6.2.2 When a rotating machine is connected to a supply system with harmonic distortion the rating of the machine is to allow for the increased heating effect of the harmonic loading.

6.2.3 The design and construction of smoke extraction fan motors are to be suitable for the ambient temperature and operating time required. Type test reports to verify the performance of the electric motor are to be submitted for consideration.

6.3 Temperature rise

6.3.1 The limits of temperature rise specified in *Table 3.6.1 Limits of temperature rise of machines cooled by air*, are based on the cooling air temperature and cooling water temperature given in *Table 3.4.1 Ambient operating conditions*, *Vol 2, Pt 1, Ch 3, 4.5 Ambient operating conditions*.

Table 3.6.1 Limits of temperature rise of machines cooled by air

Limits of temperature rise of machines cooled by air, °C								
Part of machine			Method of temperature measurement	Insulation class				
				A	E	B	F	H
1.	(a)	a.c. windings of machines having output of 5000 kVA or more	ETD	55	—	75	95	115
			R	50	—	70	90	110
	(b)	a.c. windings of machines having output of less than 5000 kVA	ETD	55	—	80	100	115
			R	50	65	70	95	110
2.		Windings of armatures having commutators	R	50	65	70	95	115
			T	40	55	60	75	95
3.		Field windings of a.c and d.c machines having d.c excitation other than those in item 4	R	50	65	70	95	115
			T	40	55	60	75	95
4.	(a)	Field windings of synchronous machines with cylindrical roots having d.c. excitation	R	—	—	80	100	125
	(b)	Stationary field windings of d.c. machines having more than one layer	R	50	65	70	95	115
			T	40	55	60	75	95
	(c)	Low resistance field windings of a.c. and d.c. machine and compensating windings of d.c. machines having more than one layer	R, T	50	65	70	90	115
	(d)	Single-layer windings of a.c. and d.c. machines with exposed, bare or varnished metal surfaces and single-layer compensating windings of d.c. machines	R, T	55	70	80	100	125
5.		Permanently short-circuited insulated windings	T	50	65	70	90	115
6.		Permanently short-circuited uninsulated windings	T	The temperature rise of these parts shall in no case reach such a value that there is a risk to any insulation or other materials on adjacent parts or to the item itself				
7.		Magnetic cores and other parts not in contact with windings						
8.		Magnetic cores and other parts in contact with windings	T	50	65	70	90	110

9. Commulators and slip-rings open and enclosed	T	50	60	70	80	90
Note 1. Where water cooled heat exchangers are used in the machine cooling circuit the temperature rises are to be measured with respect to the temperature of the cooling water at the inlet to the heat exchanger and the temperature rises given in *Table 3.6.1 Limits of temperature rise of machines cooled by air* shall be increased by 10°C provided the inlet water temperature does not exceed the values given in *Table 3.4.1 Ambient operating conditions*.,						
Note 2. T = thermometer method R = resistance method ETD = embedded temperature detector						
Note 3. Temperature rise measurements are to use the resistance method whenever practicable.						
Note 4. The ETD method may only be used when the ETD's are located between coil sides in the slot.						

6.3.2 If it is known that the temperature of cooling medium exceeds the values given in *Table 3.4.1 Ambient operating conditions*, Pt 1, Ch 3, 4.5 the permissible temperature rise is to be reduced by an amount equal to the excess temperature of the cooling medium.

6.3.3 If it is known that the temperature of cooling medium will be permanently less than the values given in *Table 3.4.1 Ambient operating conditions*, Pt 1, Ch 3, 4.5 the permissible temperature rise may be increased by an amount equal to the difference between the declared temperature and that given in *Table 3.4.1 Ambient operating conditions*, Pt 1, Ch 3, 4.5 up to a maximum of 15ºC.

6.4 Overloads

6.4.1 Motors are to withstand on test, without injury, the following momentary overloads:

At rated speed or, in the case of a range of speeds, at the highest and lowest speeds, under gradual increase of torque, the appropriate excess torque given below. Synchronous motors and synchronous induction motors are required to withstand the excess torque without falling out of synchronism and without adjustment of the excitation circuit preset at the value corresponding to rated load:

d.c. motors	50 per cent for 15 seconds;
polyphase a.c. synchronous motors	50 per cent for 15 seconds;
polyphase a.c. synchronous induction motors	35 per cent for 15 seconds;
polyphase a.c. induction motors	60 per cent for 15 seconds.

6.5 Machine enclosure

6.5.1 Where liquid-cooled heat exchangers are used in the machine cooling circuit there is to be provision to detect leakage of the liquid, and the system is to be arranged so as to prevent the entry of liquid into the machine.

6.6 Direct current machines

6.6.1 The final running position of brushgear is to be clearly and permanently marked.

6.6.2 Direct current machines are to work with fixed brush setting from no load to the momentary overload specified without injurious sparking.

6.7 Survey and testing

6.7.1 On machines for Mobility or Ship Type systems, tests are to be carried out and a certificate furnished by the manufacturer. The tests are to include temperature rise, momentary overload, high voltage, and commutation. The insulation resistance and the temperature at which it was measured are to be recorded, *see also Vol 2, Pt 9, Ch 1, 1.6 Surveys 1.6.2*.

6.7.2 In the case of duplicate machines, type tests of temperature rise, excess current and torque and commutation taken on a machine identical in rating and in all other essential details may be accepted in conjunction with abbreviated tests on each machine. Type tests for propulsion machines will be specially considered, *see also Vol 2, Pt 4, Ch 5, 4 Electric propulsion systems*.

For the abbreviated tests, each machine is to be run and is to be found electrically and mechanically sound and is to have a high voltage test and insulation resistance recorded.

6.7.3 A high voltage test, in accordance with *Vol 2, Pt 9, Ch 10, 1 Functional requirements*, is to be applied to new machines, preferably at the conclusion of the temperature rise test. Where both ends of each phase are brought out to accessible separate terminals, each phase is to be tested separately.

6.7.4 Survey during manufacture, *see Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review*, is to be conducted prior to testing of the completed machine and is to include inspection of rotor and stator assemblies to assess compliance with the constructional requirements of the relevant standards and this Section.

6.7.5 For high voltage machines, a description of rotor and stator insulation system application procedures (taping, impregnation, pressing and curing, etc.) with application process records, including details of checks and tests conducted to verify successful application, is to be made available to the LR Surveyor during manufacture, *see also Vol 2, Pt 9, Ch 3, 6.1 General requirements 6.1.4*.

6.7.6 Routine impulse tests are to be carried out on the coils of high voltage machines in accordance with IEC 60034-15: *Rotating electrical machines – Part 15: Impulse voltage withstand levels of form-wound stator coils for rotating a.c. machines*, in order to demonstrate a satisfactory withstand level of the inter-turn insulation to voltage surges. The test is to be carried out on all coils after they have been inserted in the slots and after wedging and bracing. Each coil shall be subjected to at least five impulses of injected voltage, the peak value of the injected voltage being given by the formula:

V peak = 2,45V

where

V = rated line voltage r.m.s.

Alternative proposals to demonstrate the withstand level of interturn insulation will be considered.

■ *Section 7* **Converter equipment**

7.1 Transformers

7.1.1 Paragraphs *Vol 2, Pt 9, Ch 3, 7.1 Transformers 7.1.2* apply to transformers rated for 5 kVA upwards.

7.1.2 Transformers are to comply with the requirements of the following standards as appropriate:

(a) IEC 60076 (all parts): *Power transformers*
(b) IEC 60092-503: *Electrical installations in ships – Part 503: Special features – AC supply systems with voltages in the range of above 1 kV up to and including 15 kV*; or
(c) an acceptable and relevant National Standard amended where necessary for ambient temperature, *see Table 3.4.1 Ambient operating conditions*,Pt 1, Ch 3,4.5.

7.1.3 Transformers may be of the dry type, encapsulated or liquid filled type.

7.1.4 The temperature rise of the winding of transformers above the ambient temperatures given in *Table 3.4.1 Ambient operating conditions*, Pt 1, Ch 3, 4.5, when measured by resistance during continuous operation at the maximum rating, is not to exceed:

(a) For dry type transformers, air cooled:

insulation of Class A – 50ºC

insulation of Class E – 60ºC

insulation of Class B – 70ºC

insulation of Class F – 90ºC

insulation of Class H – 110ºC

(b) For liquid filled transformers:

50ºC – where air provides cooling of the fluid

65ºC – where water provides cooling of the fluid.

7.1.5 When a transformer is connected to a supply system with harmonic distortion, the rating of the transformer is to allow for the increased heating effect of the harmonic loading. Special attention is to be given to transformers connected for the purpose of reducing harmonic distortion.

7.1.6 The inherent regulation of transformers at their rated output is to be such that the total percentage voltage drop to any point in the installation does not exceed that allowed by *Vol 2, Pt 9, Ch 1, 2.1 Quality of power supplies (QPS) 2.1.2*.

7.1.7 Transformers, except those for motor starting, are to be double wound.

7.1.8 Liquid fillings for transformers are to be non-toxic and of a type which does not readily support combustion. Liquid filled transformers are to have a pressure relief-device with an alarm and there is to be a suitable means provided to contain any liquid which may escape from the transformer due to the operation of the relief device or damage to the tank.

7.1.9 All transformers are to be capable of withstanding for two seconds, without damage, the thermal and mechanical effects of a short-circuit at the terminals of any winding.

7.1.10 When forced cooling is used, whether air or liquid, there is to be monitoring of the cooling medium and transformer winding temperatures with an alarm should these exceed preset limits. There are to be arrangements so that the load may be reduced to a level commensurate with the cooling available.

7.1.11 Transformers for propulsion power are to be provided with arrangements such that, in the event of excessive winding temperature, an alarm is initiated and:

- the load is reduced to a level commensurate with the cooling arrangements; or
- automatic shutdown of the transformer occurs.

7.1.12 Where liquid-cooled heat exchangers are used in transformer cooling circuits, there is to be provision to detect leakage of the liquid, and the system is to be arranged so as to prevent the entry of liquid into the transformer.

7.1.13 The following tests are to be carried out on all transformers at the manufacturer's works, and a certificate of tests is to be issued by the manufacturer, *see also Vol 2, Pt 9, Ch 1, 1.6 Surveys 1.6.2* and *Vol 2, Pt 9, Ch 1, 1.6 Surveys 1.6.3*:

(a) measurement of winding resistances, voltage ratio, impedance voltage, short-circuit impedance, insulation resistance, load loss, no load loss and current;
(b) dielectric tests;
(c) temperature rise test on one transformer of each size and type; and
(d) where evidence of compliance with *Vol 2, Pt 9, Ch 3, 7.1 Transformers 7.1.9* is not submitted for consideration, short-circuit withstand on one transformer of each size and type.

7.2 Semiconductor converters

7.2.1 The requirements of *Vol 2, Pt 9, Ch 3, 7.2 Semiconductor converters 7.2.2* apply to semiconductor converters rated for 5 kW upwards.

7.2.2 Semiconductor converters are to comply with the requirements of IEC 60146: *Semiconductor converters* (all parts), or an acceptable and relevant National Standard amended where necessary for ambient temperature, *see Table 3.4.1 Ambient operating conditions*.

7.2.3 Semiconductor static power converter are to be rated for the required duty having regard to peak loads, system transients and overvoltage.

7.2.4 Converter equipment may be air or liquid cooled and is to be so arranged that it cannot remain loaded unless effective cooling is maintained. Alternatively, the load may be automatically reduced to a level commensurate with the cooling available.

7.2.5 Liquid cooled converter equipment is to be provided with leakage alarms and there is to be a suitable means provided to contain any liquid which may leak from the system in order to ensure that it does not cause an electrical failure of the equipment. Where the semiconductors and other current carrying parts are in direct contact with the cooling liquid, the liquid is to be monitored for satisfactory resistivity and an alarm initiated at the relevant control station should the resistivity be outside the agreed limits.

7.2.6 Where forced cooling is used there is to be temperature monitoring of the heated cooling medium with an alarm and shutdown when the temperature exceeds a preset value.

7.2.7 Cooling fluids are to be non-toxic and of low flammability.

7.2.8 Converter equipment is to be so arranged that the semiconductor devices, fuses, control and firing circuit boards may be readily removed from the equipment for repair or replacement.

7.2.9 Test and monitoring facilities are to be provided to permit identification of control circuit faults and faulty components.

7.2.10 Protection devices fitted for converter equipment protection are to ensure that, under fault conditions, the protective action of circuit breakers, fuses or control systems is such that there is no further damage to the converter or the installation.

7.2.11 Converter equipment, including any associated transformers, reactors, capacitors and filters, if provided, is to be so arranged that the harmonic distortion, and voltage spikes, introduced into the ships electrical system are within the limits of *Vol 2, Pt 9, Ch 1, 2.1 Quality of power supplies (QPS) 2.1.3* or restricted to a lower level necessary to ensure that it causes no malfunction of equipment connected to the electrical installation. Converter equipment cables may carry high frequency currents that can cause interference. These cables are to be kept as short as possible and installed as far away as possible from sensitive signal cables.

7.2.12 Overvoltage spikes or oscillations caused by commutation or other phenomena, are not to result in the supply voltage waveform deviating from a superimposed equivalent sine wave by more than 10 per cent of the maximum value of the equivalent sine wave.

7.2.13 When converter equipment is operated in parallel, load sharing is to be such that under normal operating conditions overloading of any unit does not occur and the combination of paralleled equipment is stable throughout the operating range.

7.2.14 When converter equipment has parallel circuits there is to be provision to ensure that the load is distributed uniformly between the parallel paths.

7.2.15 Transformers, reactors, capacitors and other circuit devices associated with converter equipment, or associated filters, are to be suitable for the distorted voltage and current waveforms to which they may be subjected and filter circuits are to be provided with facilities to ensure that their capacitors are discharged before the circuits are energised.

7.2.16 Any regenerated power developed during the operation of converter equipment is not to result in disturbances to the supply system voltage and frequency which exceeds the limits of *Vol 2, Pt 9, Ch 1, 2.1 Quality of power supplies (QPS)*.

7.2.17 Where control systems form an integral part of semiconductor equipment, they are to be designed and manufactured with regard to the environmental conditions to which they will be exposed in service and their performance is to be demonstrated during the test and trials programme.

7.2.18 Tests at the manufacturer's works of converter equipment and any associated reactors or filters are to include the high voltage test of *Vol 2, Pt 9, Ch 11, 1.1 Testing*, a temperature rise test on one of each size and type of converter equipment, and such other tests as may be necessary to demonstrate the suitability of the equipment for its intended duty. Details of tests are to be submitted for consideration when required, *see also Vol 2, Pt 9, Ch 1, 1.6 Surveys 1.6.2*.

7.3 Uninterruptible power systems

7.3.1 The requirements of this sub-Section apply to all uninterruptible power systems (UPS) intended to maintain Mobility or Ship Type systems, or provide emergency services. This sub-Section is in addition to the requirements of *Vol 2, Pt 9, Ch 3, 7.1 Transformers* to *Vol 2, Pt 9, Ch 3, 7.2 Semiconductor converters* and *Vol 2, Pt 9, Ch 2, 7 Batteries*, as applicable.

7.3.2 UPS units are to be constructed in accordance with IEC 62040: *Uninterruptible power systems (UPS)*(all parts), or an acceptable and relevant National or International Standard.

7.3.3 The operation of a UPS is not to depend upon external services.

7.3.4 The type of UPS unit employed, whether off-line, line-interactive or on-line, is to be appropriate to the power supply requirements of the connected load equipment.

7.3.5 An external bypass, that is hardwired and manually operated, is to be provided for UPS to allow isolation of UPS for safety during maintenance and maintain continuity of load power.

7.3.6 UPS units are to be monitored and an audible and visual alarm is to be initiated in the navigating bridge or the engine control room, or an equivalent attended location for:

- power supply failure (voltage and frequency) to the connected load;
- earth fault;
- operation of battery protective device;
- battery discharge; and

- bypass in operation for on-line UPS units.

7.3.7 UPS units required to provide emergency services are to be suitably located for use in an emergency.

7.3.8 UPS units utilising valve-regulated sealed batteries may be located in compartments with standard marine or industrial electrical equipment provided that the arrangements comply with *Vol 2, Pt 9, Ch 2, 7.3 Location 7.3.5*. Ventilation arrangements in accordance with IEC 62040-1: *Uninterruptible power systems (UPS) – Part 1: General and safety requirements for UPS*, or an acceptable and relevant National or International Standard, may be considered to satisfy the requirements off *Vol 2, Pt 9, Ch 2, 7.5 Ventilation 7.5.10*.

7.3.9 Output power is to be maintained for the duration required for the connected equipment.

7.3.10 The UPS battery capacity is, at all times, to be capable of supplying the designated loads for the time specified. Where it is proposed that additional circuits are connected to the UPS unit, details verifying that the UPS unit has adequate capacity are to be submitted for consideration, *see Vol 2, Pt 9, Ch 1, 1.7 Alterations and additions*.

7.3.11 On restoration of the input power, the rating of the charge unit is to be sufficient to recharge the batteries in a reasonable time while maintaining the output supply to the load equipment.

7.3.12 Tests at the manufacturer's works or after installation on board are to include such tests necessary to demonstrate to the Surveyor's satisfaction the suitability of the UPS unit for its intended duty and location. As a minimum, the following tests are required:

- a temperature rise test
- battery capacity test;
- a ventilation rate test of both the equipment housing and the space into which it is to be located, *see* also *Vol 2, Pt 9, Ch 2, 7.5 Ventilation*; and
- functional testing, including operation of alarms.

Details of tests are to be submitted for consideration when required, *see also Vol 2, Pt 9, Ch 1, 1.6 Surveys 1.6.2*.

7.3.13 Where the supply is to be maintained without a break following a power input failure, this is to be verified after installation by practical testing.

■ *Section 8*
Electric cables, optical fibre cables and busbar trunking systems (busways)

8.1 General

8.1.1 The requirements of *Vol 2, Pt 9, Ch 3, 8.1 General* apply to all electric and optical fibre cables for fixed wiring unless otherwise exempted. The requirements of *Vol 2, Pt 9, Ch 3, 8.17 Busbar trunking systems (bustrunks)* apply to busbar trunking systems (busways) where they are used in place of electric cables.

8.1.2 Electric cables for fixed wiring are to be designed, manufactured and tested in accordance with the IEC Standards specified in *Table 3.8.1 Electric cables* or a specified standard acceptable to the Naval Administration. On application, LR may be able to assess the acceptability of cables in accordance with specified standards other than the relevant IEC Standards, *see also Vol 2, Pt 9, Ch 1, 1.2 Application 1.2.4*.

Table 3.8.1 Electric cables

Application	IEC Standard	Title
General constructional and testing requirements	60092–350	Electrical installations in ships – Part 350: General construction and test methods of power, control and instrumentation cables for shipboard and offshore applications
Fixed power and control circuits	60092–353	Electrical installations in ships – Part 353: Power cables for rated voltages 1 kV and 3 kV

Fixed power circuits	60092–354	Electrical installations in ships – Part 354: Single and three-core power cables with extruded solid insulation for rated voltages 6 kV (Um = 7,2 kV) up to 30 kV (Um = 36 kV)
Instrumentation, control and communication circuits up to 60 V	60092-370	Electrical installations in ships – Part 370: Guidance on the selection of cables for telecommunication and data transfer including radio-frequency cables
Control and instrumentation circuits up to 250 V	60092–376	Electrical installations in ships – Part 376: Cables for control and instrumentation circuits 150/250 V (300 V)
Mineral insulated	60702 (all parts)	Mineral insulated cables and their terminations with a rated voltage not exceeding 750 V

8.1.3 Details of optical fibre cables for fixed installation are to be submitted to assess compliance with applicable international or National Standards. These are to include:

- Flame retardancy;
- Fire resistance (if applicable);
- Smoke density;
- Halogen content;
- Mechanical properties;
- Suitability for use in the marine environment.

8.1.4 Surveys of cables for electric propulsion systems during manufacture and testing, *see Vol 2, Pt 9, Ch 1, 1.6 Surveys 1.6.3*, are to assess compliance with the applicable International, National or Naval Standards and the application of an acceptable quality management system.

8.1.5 Where increased flexibility is required due to confines of space, cables having Class 5 stranded conductors in accordance with IEC 60228 *Conductors of insulated cables* may be accepted provided *Vol 2, Pt 9, Ch 3, 8.1 General 8.1.2* is otherwise complied with. Provided that the adequate flexibility of the finished cable is assured, conductors of nominal cross-sectional area 2,5 mm^2 and less need not be stranded.

8.1.6 Electric and optical fibre cables for non-fixed applications are to comply with a relevant National or International Standard.

8.1.7 For the purpose of this Section, pipes, conduits, trunking or any other system for the additional mechanical protection of cables are hereinafter referred to under the generic name 'protective casings'.

8.1.8 Electrical cables for telecommunications and data transfer are, whenever practicable, to be selected in accordance with the recommendations of IEC TR 60092-370, *Guidance on the selection of cables for telecommunication and data transfer including radio-frequency cables.*

8.2 Testing

8.2.1 Routine tests, consisting of at least:

(a) measurement of electrical resistance of conductors;
(b) high voltage test, *see also Vol 2, Pt 9, Ch 10, 1 Functional requirements*;
(c) insulation resistance measurement;
(d) for high voltage cables, partial discharge tests are to be made in accordance with the requirements of IEC 60885-2:*Electrical test methods for electric cables– Part 2: Partial discharge tests*, or a relevant National Standard, at the manufacturer's works prior to despatch.

Evidence of successful completion of routine tests is to be provided by the manufacturer, *see also Vol 2, Pt 9, Ch 1, 1.6 Surveys 1.6.3*.

8.2.2 Particular, special and type tests are to be made, when required, in accordance with the requirements of the relevant publication or National Standard referred to in *Vol 2, Pt 9, Ch 3, 8.1 General 8.1.2*, and a test report issued by the manufacturer.

8.3 Voltage rating

8.3.1 The rated voltage of any electric cable is to be not lower than the nominal voltage of the circuit for which it is used. The maximum sustained voltage of the circuit is not to exceed the maximum voltage for which the cable has been designed.

8.3.2 Electric cables used in unearthed systems are to be suitably rated to withstand the additional stresses imposed on the insulation due to an earth fault.

8.4 Operating temperature

8.4.1 The maximum rated conductor temperature of the insulating material for normal operation is to be at least 10ºC higher than the maximum ambient temperature liable to be produced in the space where the cable is installed.

8.4.2 The maximum rated conductor temperatures for normal and short circuit operation, for the insulating materials included within the standards referred to in *Vol 2, Pt 9, Ch 3, 8.1 General 8.1.2*, is not to exceed the values stated in *Table 3.8.2 Maximum rated conductor temperature*

Table 3.8.2 Maximum rated conductor temperature

Type of insulating compound	Maximum rated conductor temperature, °C	
	Normal operation	Short-circuit
Thermoplastic based upon:		
Vinyl acetate	70	150
Elastomeric or thermosetting, based upon:		
Ethylene-propylene rubber or similar (EPM or EPDM)	90	250
High modulus or hard grade ethylene propylene rubber	90	250
Cross-linked polyethylene	90	250
Ethylene-propylene rubber or similar (EPM or EPDM) halogen-free	90	250
High modulus or hard grade halogen-free ethylene propylene rubber	90	250
Halogen-free cross-linked polyethylene	90	250
Cross-linked polyolefin material for halogen-free cables	90	250
Halogen-free silicone rubber	95	350

8.4.3 Electric cables constructed of an insulating material not included in *Table 3.8.2 Maximum rated conductor temperature* are to be rated in accordance with the National Standard chosen in compliance with *Vol 2, Pt 9, Ch 3, 8.1 General 8.1.2*.

8.5 Construction

8.5.1 Electric and optical fibre cables are to be at least of a flame-retardant, low smoke, halogen free type. Compliance with IEC 60332-1-2: *Tests on electric and optical fibre cables under fire conditions - Part 1-2: Test for vertical flame propagation for a single insulated wire or cable - Procedure for 1kW pre-mixed flame*, IEC 61034: *Measurements of smoke density of electric cables burning under defined conditions*, IEC 60754: *Tests on gases evolved during combustion of materials from cables* will be acceptable. Where cables are installed in bunches, the requirements of *Vol 2, Pt 9, Ch 3, 8.8 Installation of electric cables 8.8.10* are to be satisfied. Alternative proposals for equipment cabling that demonstrate satisfactory smoke and toxicity performance under fire conditions for identified areas of a ship may be submitted for consideration.

8.5.2 Exemption from the requirements of *Vol 2, Pt 9, Ch 3, 8.5 Construction 8.5.1* for applications such as radio frequency or digital communication systems, which require the use of particular types of cable, will be subject to special consideration.

8.5.3 Where electric or optical fibre cables are required to be of a 'fire resistant type', they are in addition to be easily distinguishable and comply with the performance requirements of the appropriate part of IEC 60331: *Tests for electric cables under fire conditions - Circuit integrity*, when tested with a minimum flame application time of 90 minutes, as follows:

IEC 60331-1: *Tests for electric cables under fire conditions – Circuit integrity – Part 1: Test method for fire with shock at a temperature of at least 830°C for cables of rated voltage up to and including 0,6/1,0 kV and with an overall diameter exceeding 20 mm*;

IEC 60331-21: *Tests for electric cables under fire conditions – Circuit integrity – Part 21: Procedures and requirements - Cables of rated voltage up to and including 0, 6/1, 0kV;*;

IEC 60331-23: *Tests for electric cables under fire conditions – Circuit integrity – Part 23: Procedures and requirements - Electric data cables; or*;

IEC 60331-25: *Tests for electric cables under fire conditions – Circuit integrity – Part 25: Procedures and requirements - Optical fibre cables.*.

8.5.4 Where electric or optical fibre cables are installed in locations exposed to the weather, in damp and in wet situations, in machinery compartments, refrigerated spaces or exposed to harmful vapours including oil vapour, they are to have the conductor insulating materials or optical fibres enclosed in an impervious sheath of material appropriate to the expected ambient conditions.

8.5.5 Where electric or optical fibre cables are installed in locations which are totally submerged for extended periods of time, they are to have the conductor insulating materials or fibres enclosed in an impervious sheath of material appropriate to the expected submerged conditions and duration.

8.5.6 Where it is required that the construction of electric or optical fibre cables includes metallic sheaths, armouring or braids, they are to be provided with an overall impervious sheath or other means to protect the metallic elements against corrosion, *see also Vol 2, Pt 9, Ch 3, 8.8 Installation of electric cables 8.8.7* and *Vol 2, Pt 9, Ch 3, 8.8 Installation of electric cables 8.8.8*.

8.5.7 Where cables are installed in an area where contamination by oil is likely to occur, the oversheath is to be of an enhanced oil resistance grade.

8.5.8 Where single core electric cables are used in circuits rated in excess of 20 Amps and are armoured, the armour is to be of a non-magnetic material.

8.5.9 Electric cables are to be constructed such that they are capable of withstanding the mechanical and thermal effects of the maximum short circuit current which can flow in any part of the circuit in which they are installed, taking into consideration not only the time/current characteristics of the circuit protective device but also the peak value of the prospective short circuit current. Where electric cables are to be used in circuits with a maximum short circuit current in excess of 70 kA, evidence is to be submitted for consideration when required demonstrating that the cable construction can withstand the effects of the short circuit current.

8.5.10 All high voltage electric cables are to be readily identified by suitable marking.

8.6 Conductor size

8.6.1 The maximum continuous load carried by a cable is not to exceed its continuous current rating. It is to be chosen such that the maximum rated conductor temperature for normal operation for the insulation is not exceeded. In assessing the current rating the correction factors in *Vol 2, Pt 9, Ch 3, 8.7 Correction factors for cable current rating* may be applied as required.

8.6.2 The cross-sectional area of the conductors is to be sufficient to ensure that, under short circuit conditions, the maximum rated conductor temperature for short circuit operation is not exceeded, taking into consideration the time current characteristics of the circuit protective device and the peak value of the prospective short circuit current.

8.6.3 The cable current ratings given in *Table 3.8.3 Electric cable current ratings, normal operation, based on ambient 45°C* and *Table 3.8.4 Electric cable current ratings, r.m.s. short circuit current* are based on the maximum rated conductor temperatures given in *Table 3.8.2 Maximum rated conductor temperature*. When cable sizes are selected on the basis of precise evaluation of current rating based upon experimental and calculated data, details are to be submitted for consideration. Alternative short circuit temperature limits, other than those given in *Table 3.8.4 Electric cable current ratings, r.m.s. short circuit current*, may be applied using the data provided in:

- IEC 60724:*Short-circuit temperature limits of electric cables with rated voltages of 1kV (Um=1,2kV) and 3kV (Um=3,6kV)*;or

- IEC 60986: *Short-circuit temperature limits of electric cables with rated voltages from 6kV (Um=7,2kV) and up to 30kV (Um=36kV)*.

Alternative short-circuit temperature limits provided in an acceptable and relevant National Standard may also be considered.

Table 3.8.3 Electric cable current ratings, normal operation, based on ambient 45°C

Nominal cross section (mm^2)	Continuous r.m.s. current rating, in amperes								
	Thermoplastic (70°C)			Elastomeric (90°C)			Elastomeric or thermosetting, based on silicone rubber (95°C)		
	single core	2 core	3 or 4 core	single core	2 core	3 or 4 core	single core	2 core	3 or 4 core
0,75	10	8	7	15	13	11	17	14	12
1	12	10	8	18	15	13	20	17	14
1,25	13	11	9	21	18	14	23	20	16
1,5	15	13	11	23	20	16	26	22	18
2	18	15	12	28	24	19	31	26	22
2,5	21	18	15	30	26	21	32	27	22
3,5	26	22	18	37	32	26	39	33	28
4	29	25	20	40	34	28	43	37	30
5,5	35	30	24	49	42	35	52	44	37
6	37	31	26	52	44	36	55	47	39
8	44	37	31	62	53	44	66	56	46
10	51	43	36	72	61	50	76	65	53
14	62	53	44	88	75	62	94	80	66
16	68	58	48	96	82	67	102	87	71
22	83	70	58	117	100	82	124	106	87
25	90	77	63	127	108	89	135	115	95
30	101	85	70	142	121	100	151	128	106
35	111	94	78	157	133	110	166	141	116
38	117	99	82	165	140	116	175	149	122
50	138	117	97	196	167	137	208	177	146
60	155	132	109	220	187	154	233	198	163
70	171	145	120	242	206	169	256	218	179
80	186	158	130	263	224	184	278	237	195
95	207	176	145	293	249	205	310	264	217
100	213	181	149	302	257	212	320	272	224
120	239	203	167	339	288	237	359	305	251
125	245	209	172	348	295	243	368	313	258
150	275	234	193	389	331	272	412	350	288
185	313	266	219	444	377	311	470	400	329
200	329	280	230	466	396	326	494	420	346
240	369	314	258	522	444	365	553	470	387
300	424	360	297	601	511	421	636	541	445

Table 3.8.4 Electric cable current ratings, r.m.s. short circuit current

Nominal cross section (mm^2)	Fault current (kA) at 150°C			Fault current (kA) at 250°C			Fault current (kA) at 350°C		
	1s duration	0,5s duration	0,1s duration	1s duration	0,5s duration	0,1s duration	1s duration	0,5s duration	0,1s duration
0,75	0,1	0,1	0,3	0,1	0,2	0,3	0,1	0,2	0,4
1	0,1	0,2	0,3	0,1	0,2	0,5	0,2	0,2	0,5
1,25	0,1	0,2	0,4	0,2	0,3	0,6	0,2	0,3	0,7
1,5	0,2	0,2	0,5	0,2	0,3	0,7	0,3	0,4	0,8
2	0,2	0,3	0,7	0,3	0,4	0,9	0,3	0,5	1,1
2,5	0,3	0,4	0,9	0,4	0,5	1,1	0,4	0,6	1,4
3,5	0,4	0,5	1,2	0,5	0,7	1,6	0,6	0,8	1,9
4	0,4	0,6	1,4	0,6	0,8	1,8	0,7	1,0	2,2
5,5	0,6	0,8	1,9	0,8	1,1	2,5	0,9	1,3	3,0
6	0,7	0,9	2,1	0,9	1,2	2,7	1,0	1,5	3,2
8	0,9	1,2	2,8	1,1	1,6	3,6	1,4	1,9	4,3
10	1,1	1,5	3,5	1,4	2,0	4,5	1,7	2,4	5,4
14	1,5	2,2	4,8	2,0	2,8	6,3	2,4	3,4	7,6
16	1,7	2,5	5,5	2,3	3,2	7,2	2,7	3,9	8,7
22	2,4	3,4	7,6	3,1	4,5	10,0	3,8	5,3	11,9
25	2,7	3,9	8,6	3,6	5,1	11,3	4,3	6,0	13,5
30	3,3	4,6	10,4	4,3	6,1	13,6	5,1	7,3	16,2
35	3,8	5,4	12,1	5,0	7,1	15,8	6,0	8,5	18,9
38	4,1	5,9	13,1	5,4	7,7	17,2	6,5	9,2	20,6
50	5,5	7,7	17,3	7,2	10,1	22,6	8,6	12,1	27,1
60	6,5	9,3	20,7	8,6	12,1	27,1	10,3	14,5	32,5
70	7,6	10,8	24,2	10,0	14,2	31,7	12,0	16,9	37,9
80	8,7	12,3	37,6	11,4	16,2	36,2	13,7	19,4	43,3
95	10,4	14,7	32,8	13,6	19,2	43,0	16,3	23,0	51,4
100	10,9	15,4	34,5	14,3	20,2	45,2	17,1	24,2	54,1
120	13,1	18,5	41,4	17,2	24,3	54,3	20,5	29,0	64,9
125	13,6	19,3	43,1	17,9	25,3	56,6	21,4	30,2	67,6
150	16,4	23,2	51,8	21,5	30,4	67,9	25,7	36,3	81,2
185	20,2	28,6	63,9	26,5	37,4	83,7	31,7	44,8	100,1
200	21,8	30,9	69,0	28,6	40,5	90,5	34,2	48,4	108,2
240	26,2	37,0	82,8	34,3	48,6	108,6	41,1	58,1	129,9
300	32,7	46,3	103,6	42,9	60,7	135,7	51,3	72,6	162,3

8.6.4 The cross-sectional area of the conductors is to be sufficient to ensure that at no point in the installation will the voltage variations stated in *Vol 2, Pt 9, Ch 1, 2.1 Quality of power supplies (QPS)* be exceeded when the conductors are carrying the maximum current under their normal conditions of service.

8.6.5 The size of earth conductors is to comply with *Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding 2.4.7*.

8.6.6 The cross sectional area of conductors used in circuits supplying cyclic or non-continuous loads is to be sufficient to ensure that the cables maximum rated conductor temperature for normal operation is not exceeded when the conductors are operating under their normal conditions of service, *see Vol 2, Pt 9, Ch 3, 8.7 Correction factors for cable current rating 8.7.4*.

8.7 Correction factors for cable current rating

8.7.1 The correction factors of *Vol 2, Pt 9, Ch 3, 8.7 Correction factors for cable current rating 8.7.2* provide a guide for general applications in assessing a current rating. A more precise evaluation based upon experimental and calculated data may be submitted for consideration.

8.7.2 **Bunching of cables.** Where more than six electric cables, which may be expected to operate simultaneously at their full rated capacity, are laid close together in a cable bunch in such a way that there is an absence of free air circulation around them, a correction factor of 0,85 is to be applied. Signal cables may be exempted from this requirement.

8.7.3 **Ambient temperature.** The current ratings of *Table 3.8.3 Electric cable current ratings, normal operation, based on ambient 45°C* are based on an ambient temperature of 45ºC. For other values of ambient temperature the correction factors shown in *Table 3.8.5 Correction factors* are to be applied.

Table 3.8.5 Correction factors

Insulation material	Correction factor for ambient air temperature of °C										
	35	40	45	50	55	60	65	70	75	80	85
Thermoplastic (70°C)	1,18	1,10	1,00	0,89	0,77	0,63	–	–	–	–	–
Elastomeric or thermosetting (90°C)	1,10	1,05	1,00	0,94	0,88	0,82	0,74	0,67	0,58	0,47	–
Elastomeric or thermosetting, based on silicone rubber (95°C)	1,10	1,05	1,00	0,95	0,89	0,84	0,77	0,71	0,63	0,55	0,45

8.7.4 **Short time duty**. When the load is not continuous i.e. operates for periods of half an hour or one hour and the periods of no load are longer than three times the cable's time constant, *T*, in minutes, the cable's continuous rating may be increased by a duty factor, calculated in accordance with:

$$\text{Duty factor} = \sqrt{\frac{1,12}{1 - e^{\frac{-t_s}{T}}}}$$

When the load is not continuous, is repetitive and has periods of no-load less than three times the cable's time constant, so that the cable has insufficient time to cool down between the applications of load, the cable's continuous rating may be increased by an intermittent factor, calculated in accordance with:

$$\text{Intermittent factor} = \sqrt{\frac{1 - e^{\frac{-t_p}{T}}}{1 - e^{\frac{-t_s}{T}}}}$$

where

t_p = the intermittent period, in minutes, i.e. the total period of load and no-load before the cycle is repeated

T = $0{,}245d^{1{,}35}$ where d is the overall diameter of the cable, in mm

t_s = the service time of the load current in minutes

8.7.5 **Diversity**. Where cables are used to supply two or more final sub-circuits, account may be taken of any diversity factors which may apply, *see Vol 2, Pt 9, Ch 3, 4.6 Diversity factor*.

8.8 Installation of electric cables

8.8.1 Electric and optical fibre cable runs are to be, as far as practicable, fixed in straight lines and in accessible positions.

8.8.2 Bends in fixed electric and optical fibre cable runs are to be in accordance with the cable manufacturer's recommendations. The minimum internal radius of bend for the installation of fixed electric cables is to be chosen according to the construction and size of the cable and is not to be less than the values given in *Table 3.8.6 Minimum internal radii of bends in cables for fixed wiring*

Table 3.8.6 Minimum internal radii of bends in cables for fixed wiring

Cable construction		Overall diameter of cable	Minimum internal radius of bend (times overall diameter of cable)
Insulation	Outer covering		
Thermoplastic and elastomeric 600/1000 V and below	Metal sheathed Armoured and braided	Any	6*D*
	Other finishes	≤ 25 mm	4*D*
		> 25 mm	6*D*
Mineral	Hard metal sheathed	Any	6*D*
Thermoplastic and elastomeric above 600/1000 V – single core – multicore	Any	Any	12*D*
	Any	Any	9*D*

8.8.3 The installation of electric and optical fibre cables across expansion joints in any structure is to be avoided. Where this is not practicable, a loop of electric cable of length sufficient to accommodate the expansion of the joint is to be provided. For electric cables, the internal radius of the loop is to be at least 12 times the external diameter of the cable. For optical fibre cables, the internal radius of the loop is to meet the manufacturers' minimum recommendations.

8.8.4 Electric and optical fibre cables for Mobility systems, Ship Type systems, and emergency services are to be arranged, so far as is practicable, to avoid galleys, machinery spaces and other enclosed spaces and areas of high fire risk except as is necessary for the service being supplied. Such cables are also, so far as reasonably practicable, to be routed clear of bulkheads to preclude them being rendered unserviceable by heating of the bulkheads that may be caused by a fire in an adjacent space.

8.8.5 Electric and optical fibre cables having insulating materials with different maximum rated conductor temperatures are to be so installed that the maximum rated conductor temperature for normal operation of each cable is not exceeded.

8.8.6 Electric and optical fibre cables having a protective covering which may damage the covering of other cables are not to be bunched with those other cables.

8.8.7 Cables having an exposed metallic screen, braid or armour are to be installed in such a manner that galvanic corrosion by contact with other metals is prevented. Sufficient measures are also to be taken to prevent damage to exposed galvanised coatings during installation.

8.8.8 Protection is to be provided for cable oversheaths in areas where cables are likely to be exposed to damaging substances under normal circumstances or areas where the spillage or release of harmful substances is likely.

8.8.9 Electric and optical fibre cables are to be, as far as practicable, installed remote from sources of heat. Where installation of cables near sources of heat cannot be avoided and where there is consequently a risk of damage to the cables by heat, suitable shields, insulation or other precautions are to be installed between the cables and the heat source. The free air circulation around the cables is not to be impaired.

8.8.10 Where cables are installed in bunches, provision is to be made to limit the propagation of fire. This requirement is considered satisfied when cables of the bunch have been tested in accordance with the requirements of IEC 60332-3-22:*Tests on electric and optical fibre cables under fire conditions, Part 3-22, Test for vertical flame spread of vertically mounted bunched wires or cables - Category A*, provided that, in addition, there is no shedding of flaming droplets of sheath or insulation material and that they are installed in the same configuration(s) as used in the test(s). If the cables are not so installed, information is to be submitted in satisfactorily demonstrate that suitable measures are taken to ensure that an equivalent limit of fire propagation will be achieved for the configuration(s) used. Particular attention is to be given to cables in vertical runs in trunks and other restricted spaces. In addition, cables that comply with the requirements of IEC 60332-3-22 are also required to meet the requirements of IEC 60332-1-2: *Tests on electric and optical fibre cables under fire conditions – Part 1-2: Test for vertical flame propagation for a single insulated wire or cable – Procedure for 1 kW pre-mixed flame*.

8.8.11 Electric and optical fibre cables are not to be coated or painted with materials which may adversely affect their sheath or their fire performance.

8.8.12 Where electric and optical fibre cables are installed in refrigerated spaces, they are not to be covered with thermal insulation but may be placed directly on the face of the refrigeration chamber, provided that precautions are taken to prevent the electric cables being used as casual means of suspension.

8.8.13 All metal coverings of electric and optical fibre cables are to be earthed in accordance with *Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding* .

8.8.14 High voltage cables may be installed as follows:

(a) in the open, e.g. on carrier plating, when they are to be provided with a continuous metallic sheath or armour which is effectively bonded to earth to reduce danger to personnel. The metallic sheath or armour may be omitted provided that the cable sheathing material has a longitudinal electric resistance high enough to prevent sheath currents which may be hazardous to personnel;
(b) contained in earthed metallic protective casings when the cables may be as in (a) or the armour or metal sheath may be omitted. In the latter case care is to be taken to ensure that protective casings are electrically continuous and that short lengths of cable are not left unprotected.

8.8.15 High voltage electric cables are not to be run in the open through accommodation spaces.

8.8.16 High-voltage electric cables are to be segregated from electric cables operating at lower voltages.

8.8.17 Electric and optical fibre cables are to be, so far as reasonably practicable, installed remote from sources of mechanical damage. Where necessary, the cables are to be protected in accordance with the requirements of *Vol 2, Pt 9, Ch 3, 8.9 Mechanical protection of cables*

8.8.18 Electric and optical fibre cables, with the exception of those for portable appliances and those installed in protective casings, are to be fixed securely in accordance with the requirements of *Vol 2, Pt 9, Ch 3, 8.10 Cable support systems*

8.8.19 Electric and optical fibre cables serving any Mobility or Ship Type system, and any glands through which they pass must be able to withstand flooding for a period of 18 hours, based on the water pressure that may occur at the location.

8.8.20 Where electric and optical fibre cables penetrate bulkheads and decks, the requirements of *Vol 2, Pt 9, Ch 3, 8.11 Penetration of bulkheads and decks by cables* are to be complied with.

8.8.21 Where electric and optical fibre cables are installed in protective casings, the requirements of *Vol 2, Pt 9, Ch 3, 8.12 Installation of electric and optical fibre cables in protective casings* are to be complied with.

8.8.22 a.c. wiring is to be carried out using multicore cables wherever reasonably practicable. Where it is necessary to install single core electric cables for alternating current circuits in excess of 20 Amps the requirements of *Vol 2, Pt 9, Ch 3, 8.14 Single core electric cables for alternating current* are to be complied with. *See also Vol 2, Pt 9, Ch 3, 8.5 Construction 8.5.8*.

8.9 Mechanical protection of cables

8.9.1 Electric or optical fibre cables exposed to risk of mechanical damage are to be protected by suitable protective casings unless the protective covering (e.g. armour or sheath) is sufficient to withstand the possible cause of damage.

8.9.2 Electric or optical fibre cables installed in spaces where there is exceptional risk of mechanical damage such as hangers, storage spaces, etc. are to be suitably protected by metallic protective casings, even when armoured, unless the ship's structure affords adequate protection.

8.9.3 Metal protective casings are to be efficiently protected against corrosion, and effectively earthed in accordance with *Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding* .

8.10 Cable support systems

8.10.1 Electric cables are to be effectively supported and secured, without being damaged, to the ships' structure, either indirectly by a cable support system, or directly by means of clips, saddles or straps to bulkheads etc. *see Vol 2, Pt 9, Ch 3, 8.8 Installation of electric cables 8.8.4*

8.10.2 Cable support systems, which may be in the form of trays or plates, separate support brackets, hangers or ladder racks, together with their fixings and accessories, are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection. The cable support system is to be effectively secured to the ships' structure, the spacing of the fixings taking account of the probability of vibration and any heavy external forces, e.g. where located in areas subject to impact by sea-water. In addition, where applicable, military aspects for shock are to be defined as required by *Vol 2, Pt 1, Ch 3, 4.8 Astern power*

8.10.3 The distances between the points at which the cable is supported (e.g. distances between ladder rungs, support brackets, hangers, etc.) are to be chosen according to the construction of cable (i.e. size and rigidity) and the probability of vibration and are to be generally in accordance with those given in *Table 3.8.7 Maximum spacing of supports or fixings for securing cables*

Table 3.8.7 Maximum spacing of supports or fixings for securing cables

External diameter of cable		Non-armoured cables	Armoured cables
exceeding	not exceeding		
mm	mm	mm	mm
—	8	200	250
8	13	250	300
13	20	300	350
20	30	350	400
30	—	400	450

8.10.4 Where the cables are laid on top of their support system, the spacing of the clips, straps, etc. securing the cables may be increased beyond the spacing given in *Table 3.8.7 Maximum spacing of supports or fixings for securing cables*, but should take account of movement and vibration and in general is not to exceed 900 mm. This relaxation is not to be applied where cables can be subjected to heavy external forces, e.g. where they are run on, or above, open deck or in areas subject to sea-water impingement.

8.10.5 Single core electric cables are to be firmly fixed, using supports of strength adequate to withstand forces corresponding to the values of the peak prospective short circuit current.

8.10.6 Cables for emergency alarms and their power sources are to be in accordance with *Vol 2, Pt 9, Ch 1, 2.5 Operation under fire conditions*.

8.10.7 Electrical equipment and cables for emergency alarms are to be so arranged that the loss of alarms in any one area due to localised fire, collision, flooding or similar damage is minimised, *see Vol 2, Pt 9, Ch 1, 2.5 Operation under fire conditions* and *Vol 2, Pt 9, Ch 1, 2.6 Operation under flooding conditions*.

8.11 Penetration of bulkheads and decks by cables

8.11.1 Where electric or optical fibre cables pass through watertight, fire insulated or gastight bulkheads or decks separating hazardous zones or spaces from non-hazardous zones or spaces, the arrangements are to be such as to ensure the integrity of the bulkhead or deck is not impaired. The arrangements chosen are to ensure that the cables are not adversely affected.

8.11.2 Where cables pass through non-watertight bulkheads or structural steel, the holes are to be bushed with suitable material. If the steel is at least 6 mm thick, adequately rounded edges may be accepted as the equivalent of bushing.

8.11.3 Electric and optical fibre cables passing through decks are to be protected by deck tubes or ducts.

8.11.4 Where cables pass through thermal insulation they are to do so at right angles, in tubes sealed at both ends.

8.12 Installation of electric and optical fibre cables in protective casings

8.12.1 Protective casings are to be mechanically continuous across joints and effectively supported and secured to prevent damage to the electric or optical fibre cables.

8.12.2 Protective casings are to be suitably smooth on the interior and have their ends shaped or bushed in such a manner as not to damage the cables.

8.12.3 The internal radius of bends of protective casings are to be not less than that required for the largest cable installed therein, *see Vol 2, Pt 9, Ch 3, 8.8 Installation of electric cables 8.8.2*

8.12.4 The space factor (ratio of the sum of the cross sectional areas corresponding to the external diameters of the cables to the internal cross sectional area of the protective casings) is not to exceed 0,4.

8.12.5 Where necessary, ventilation openings are to be provided at the highest and lowest points of protective casings to permit air circulation and to prevent accumulation of water.

8.12.6 Expansion joints are to be provided in protective casings where necessary.

8.12.7 Protective casings containing high voltage electric cables are not to contain other electric or optical fibre cables and are to be clearly identified, defining their function and voltage.

8.13 Non-metallic cable support systems, protective casings and fixings

8.13.1 Where it is proposed to use non-metallic cable support systems, protective casings or fixings, the additional requirements of this sub-Section apply. Non metallic protective cases are not permitted where *Vol 2, Pt 9, Ch 3, 8.8 Installation of electric cables 8.8.14* applies.

8.13.2 Non-metallic cable support systems and protective casings are to be installed in accordance with the manufacturer's recommendations. The support systems and protective casings are to have been tested in accordance with an acceptable test procedure for:

(a) ambient operating temperatures;
(b) safe working load;
(c) impact resistance;
(d) flame retardancy;
(e) smoke and toxicity; and
(f) use in explosive gas atmospheres or in the presence of combustible dusts, electrical conductivity;

with satisfactory results.

8.13.3 Non-metallic cable support systems, protective casings and fixings installed on the open deck are to be protected from degradation caused by exposure to solar radiation.

8.13.4 Where the cable support system, protective casing or fixings are manufactured from a material other than metal, suitable supplementary metallic fixings or straps spaced at regular distances are to be provided such that, in the event of a fire or failure, the cable support system, protective casing and the affixed cables are prevented from falling and causing an injury to personnel and/or an obstruction to any escape route. Alternatively, the cables may be routed away from such areas.

8.13.5 The load on non-metallic cable support systems or protective casings is not to exceed the tested safe working load.

8.13.6 When a cable support system or protective casing is secured by means of clips or straps manufactured from a material other than metal, the fixings are to be supplemented by suitable metal clips or straps spaced at regular distances each not exceeding 2 m and, for non metallic cable support systems or protective casings, that used during safe working load testing.

8.13.7 Non-metallic fixings are to be flame retardant in accordance with the requirements of IEC 60092- 101: *Electrical installations in ships – Part 101: Definitions and general requirements*, or an alternative, relevant National or International Standard.

8.14 Single core electric cables for alternating current

8.14.1 When installed in protective casings, electric cables belonging to the same circuit are to be installed in the same casing, unless the casing is of non-magnetic material.

8.14.2 Cable clips are to include electric cables of all phases of a circuit unless the clips are of non-magnetic material.

8.14.3 Single-core cables of the same circuit are to be in contact with one another, as far as possible. In any event the distance between adjacent electric cables is not to be greater than one cable diameter.

8.14.4 If single-core cables of current rating greater than 250 A are installed near a steel bulkhead, the clearance between the cables and the bulkhead is to be at least 50 mm unless the cables belonging to the same a.c. circuit are installed in trefoil formation.

8.14.5 Magnetic material is not to be used between single core cables of a group. Where cables pass through steel plates, all the conductors of the same circuit are to pass through a plate or gland, so made that there is no magnetic material between the cables, and the clearance between the cables and the magnetic material is not to be less than 75 mm, unless the cables belonging to the same a.c. circuit are installed in trefoil formation.

8.14.6 Electric cables are to be installed such that the induced voltages, and any circulating currents, in the sheath or armour are limited to safe values.

8.15 Electric cable ends

8.15.1 Where screw-clamp or spring-clamp type terminations are used in electrical apparatus for external cable connections (*see Vol 2, Pt 9, Ch 1, 2.2 Design, construction and location 2.2.12*), cable conductors of the solid or stranded type may be inserted directly into the terminals. Where flexible conductors are used, a suitable termination is to be fitted to the cable conductor to prevent 'whiskering' of the strands.

8.15.2 If compression type conductor terminations are used on the cable ends, they are to be of a size to match the conductor and to be made with a compression type tool with the dies selected to suit the termination and conductor sizes and having a ratchet action to ensure completion of the compression action.

8.15.3 Soldered sockets may be used in conjunction with non-corrosive fluxes provided that the maximum conductor temperature at the joint, under short circuit conditions, does not exceed 160ºC.

8.15.4 High voltage cables of the radial field type, i.e. having a conducting layer to control the electric field within the insulation, are to have terminations which provide electrical stress control.

8.15.5 Electric cables having hygroscopic insulation (e.g. mineral insulated) are to have their ends sealed against ingress of moisture.

8.15.6 Cable terminations are to be of such a design and dimensions that the maximum current likely to flow through them will not result in degradation of the contacts or damage to insulation as the result of overheating or corrosion.

8.15.7 The fixing of conductors in terminals at joints and at tappings is to be capable of withstanding the thermal and mechanical effects of short circuit currents.

8.15.8 Cable terminations are to be suitable for the operating voltages and currents and may be of the screw-clamp or spring-clamp type or plug and socket connectors.

8.16 Joints and branch circuits in cable systems

8.16.1 If a joint is necessary it is to be carried out so that all conductors or fibres are adequately secured, insulated and protected from atmospheric action. The flame retardant properties or fire-resisting properties of the cable are to be retained, the continuity of metallic sheath, braid or armour is to be maintained and the current-carrying capacity or transmission of data through the cable is not to be impaired.

8.16.2 Tappings (branch circuits) are to be made in suitable boxes of such a design that the conductors remain suitably insulated, protected from atmospheric action and fitted with terminals or busbars of dimensions appropriate to the current rating.

8.16.3 Tappings and splices of optical fibre cables are to be made in accordance with the manufacturers' recommendations and are to be provided with appropriate fittings. In addition they are to be located within suitably designed enclosures to ensure that the protection of the optical fibres is maintained.

8.16.4 Cables of a fire resistant type (*see Vol 2, Pt 9, Ch 3, 8.5 Construction 8.5.3*) are to be installed so that they are continuous throughout their length without any joints or tappings.

8.17 Busbar trunking systems (bustrunks)

8.17.1 Where busbar trunking systems are used in place of electric cables, they are to comply with the requirements of *Vol 2, Pt 9, Ch 3, 8.17 Busbar trunking systems (bustrunks) 8.17.2*, in addition to the applicable requirements in *Vol 2, Pt 9, Ch 3, 5 Switchgear and controlgear assemblies*

8.17.2 The busbar trunking, or enclosure system, is to have a minimum ingress protection of IP54, according to IEC60529: *Degrees of protection provided by enclosures* (IP Code).

8.17.3 The internal and external arrangements of the busbar trunking, or enclosure system, are to ensure that the fire and/or watertight integrity of any structure through which it passes is not impaired.

8.17.4 Where the busbar trunking system is employed for circuits on and below the bulkhead deck, arrangements are to be made to ensure that circuits on other decks are not affected in the event of partial flooding under the normal angles of inclination given in *Vol 2, Pt 1, Ch 1, 4.4 Installation, integration and test principles*. and *Vol 2, Pt 1, Ch 1, 4.5 Trials principles* for Mobility or Ship Type systems.

8.17.5 Supports and accessories are to be robust and are to be of corrosion-resistant material or suitably corrosion inhibited before erection. The support system is to effectively secure the busbar trunking system to the ship's structure.

8.17.6 When accessories are fixed to the busbar system by means of clips or straps manufactured from a material other than metal, the fixings are to be supplemented by suitable metal clips or straps, such that, in the event of a fire or failure, the accessories are prevented from falling and causing injury to personnel and/or an obstruction to any escape route. Alternatively, the busbar system may be routed away from such areas.

8.18 Cable segregation

8.18.1 To reduce mutual interference, cables with different signal levels are to be grouped in accordance with *Table 3.8.8 Cable segregation groups* and installed with the separation distances as shown in *Table 3.8.9 Separation distances, mm*

Table 3.8.8 Cable segregation groups

Criteria	Signal level		HF Pulse	Group
	LF/DC	Application		
Very sensitive	1 mV	1 µV	A	Receiver antenna cables Television antenna cables (RX) Infrared receiver cables Sonar/sounder receiver cables Radio MF receiver cables Radar MF receiver cables Dynamic microphone input Servo amplifier input (asymmetric and high impedance)
Sensitive	100 mV	10 µV	B	Voltage, frequency and phase dependent signal cables Reference voltage and synchro system cables (400/1100Hz) Servo amplifier input cables (symmetric) Analogue and digital cables (symmetric and low voltage signal) M and P lines, sound powered telephone cables
Low sensitivity, low interference	24 V	10 µV	C	Power supply cables High power cables Telephone, telex, loudspeaker and signal key cables Press to talk cables Start/stop signalling cables
Interference	440 V	3 V	D	Synchronisation cables Video cables Strobe cables Marker cables Pulse cables (low power) Control cables from wide band amplifiers Digital signal cables (low level or asymmetrical and high level) High power synchro cables
High interference	440 V	30 V	E	Transmit antenna cables Main electromotor cables Modulator pulsed cables Pulse cables for high power Echo sounder transmit and receiver cables
Very sensitive with high interference	1000 V	1000 V	F	Radio transmit and receive cables Transducer cables Echo sounder transmit and receiver cables
Immune, no interference			Z	Fibre optic cables

Table 3.8.9 Separation distances, mm

Group	A	B	C	D	E	F
A	–	50	100	150	200	200
B	50	–	50	100	150	100
C	100	50	–	50	100	100
D	150	100	50	–	50	100

E	200	150	100	50	–	200
F	200	100	100	100	200	–

■ *Section 9*
Equipment – heating, lighting and accessories

9.1 Heating and cooking equipment

9.1.1 The construction of heaters is to give a degree of protection according to IEC 600529: *Degrees of protection provided by enclosures (IP Code)*, or an acceptable and relevant National Standard, suitable for the intended location.

9.1.2 Heating elements are to be suitably guarded.

9.1.3 Heating and cooking equipment is to be installed such that adjacent bulkheads and decks are not subjected to excessive heating.

9.2 Socket outlets and plugs

9.2.1 The temperature rise on the live parts of socket outlet and plugs is not to exceed 30ºC. Socket outlets and plugs are to be so constructed that they cannot be readily short-circuited whether the plug is in or out, and so that a pin of the plug cannot be made to earth either pole of the socket outlet.

9.2.2 All socket outlets of current rating in excess of 16 A are to be provided with a switch, and be interlocked such that the plug cannot be inserted or withdrawn when the switch is in the 'on' position.

9.2.3 Where it is necessary to earth the non-current carrying parts of portable or transportable equipment, an effective means of earthing is to be provided at the socket outlet.

9.2.4 On weather decks, galleys, laundries, machinery spaces and all wet situations socket outlets and plugs are to be effectively shielded against rain and spray and are to be provided with means of maintaining this quality after removal of the plug.

9.3 Enclosures

9.3.1 Enclosures for the containing and mounting of electrical accessories are to be of metal, effectively protected against corrosion, or of flame-retardant insulating materials.

■ *Section 10*
Navigation and manoeuvring systems

10.1 Steering gear

10.1.1 The requirements of *Vol 2, Pt 9, Ch 3, 10.1 Steering gear 10.1.2* are to be read in conjunction with those in *Vol 2, Pt 6, Ch 1, 7 Electrical power circuits and equipment*.

10.1.2 Two exclusive circuits, fed from the main source of electrical power and each having adequate capacity to supply all the motors which may be connected to it simultaneously, are to be provided for each electric or electrohydraulic steering gear arrangement consisting of one or more electric motors. One of these circuits may pass through the emergency switchboard, if installed, *see also Vol 2, Pt 6, Ch 1, 7 Electrical power circuits and equipment*.

10.1.3 The main and auxiliary steering gear motors are to be capable of being started from a position on the navigating bridge and also arranged to restart automatically when power is restored after a power failure.

10.1.4 The motor of an associated auxiliary electric or electrohydraulic power unit may be connected to one of the circuits supplying the main steering gear.

10.1.5 Only short circuit protection is to be provided for each main and auxiliary steering gear motor circuit.

10.1.6 Where specified and agreed by the Naval Authority, in ships of category NS3, if an auxiliary steering gear is not electrically powered or is powered by an electric motor primarily intended for other services, the main steering gear may be fed by one circuit from the main switchboard. Consideration would be given to other protective arrangements other than described in *Vol 2, Pt 9, Ch 3, 10.1 Steering gear 10.1.5* for such a motor primarily intended for other services.

10.1.7 Each main and auxiliary steering gear electric control system which is to be operated from the navigating bridge is to be served with electric power by a separate circuit supplied from the associated steering gear power circuit, from a point within the steering gear compartment, or directly from the same section of switchboard busbars, main or emergency, to which the associated steering gear power circuit is connected. Each separate circuit is to be provided with short circuit protection only.

10.2 Thruster systems for steering

10.2.1 Where azimuth or rotatable thruster units, used as the sole means of steering, are electrically driven the requirements of *Vol 2, Pt 4, Ch 3, 7 Electrical systems* are to be complied with.

10.3 Thruster systems for manoeuvring

10.3.1 Where a thruster unit is fitted solely for the purpose of manoeuvring, and is electrically driven, its starting and operation is not to cause the loss of any Mobility systems or Ship Type systems.

10.3.2 In order to ensure that the thruster system is not tripped inadvertently whilst manoeuvring the ship, overload protection in the form of an alarm is to be provided for the electric motor and any associated supply converters, in lieu of tripping.

10.3.3 The thruster unit electric motor is not to be disconnected as part of a load management switching operation.

10.4 Navigational aids

10.4.1 Navigational aids are to be fed from the emergency source of electrical power. *See also Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7*.

10.4.2 For ships with navigational arrangements of one watchkeeper, navigational aids are to have an alternative supply fed from the main source of electrical power, independent of the emergency switchboard, with automatic change-over facilities.

■ Scope

The requirements of this Chapter are applicable to the design and co-ordination of the electrical protection philosophy of the electrical generation and distribution systems and connected auxiliary consumers.

This Chapter details the requirements for protection of the electrical generation and distribution systems and connected equipment to provide continuity of service and protection of equipment and personnel from fire and other hazards resulting from electrical failures.

Application of this Chapter will facilitate the verification of the performance requirements of *ANEP-77, NATO Naval Ship Code* Chapter IV Regulation 10.

■ *Section 1*
Functional requirements

1.1 Functional requirements

1.1.1 All electrical equipment shall be suitably protected against damage to itself under normal, reasonable foreseeable abnormal and fault conditions and to prevent injury to personnel or damage to other equipment.

■ *Section 2*
Performance requirements

2.1 Performance requirements

2.1.1 Efficient means, suitably located, shall be provided for protecting from excess of current every part of a system as may be necessary to prevent danger.

2.1.2 Suitable arrangements for the protection of mechanically connected equipment due to the effects of electrical overloads shall be provided.

2.1.3 Suitable arrangements for the protection of electrical equipment due to the effects of mechanical overloads shall be provided.

2.1.4 Suitable protection arrangements for lightning strikes shall be provided.

2.1.5 Personnel, equipment and platform are to be protected from the risk of static electricity.

■ Section 3 Verification requirements

3.1 General

3.1.1 Compliance with the requirements in*Vol 2, Pt 9, Ch 4, 4 System design - protection* inclusive is deemed to satisfy the functional requirements and performance requirements above.

3.1.2 Where a designer offers a novel solution, an engineering safety and justification report is to be submitted. The engineering safety and justification report is to demonstrate how the proposed solution will satisfy the functional requirements and performance requirements in *Vol 2, Pt 9, Ch 4, 1 Functional requirements* and *Vol 2, Pt 9, Ch 4, 2 Performance requirements*.

3.1.3 The Naval Administration may impose requirements additional to those in this Chapter.

■ Section 4 System design - protection

4.1 General

4.1.1 Installations are to be protected against overcurrents including short-circuits, and other electrical faults. The tripping/fault clearance times of the protective devices are to provide complete and co-ordinated protection to ensure:

(a) availability of Mobility systems, Ship Type systems, and emergency services under fault conditions through discriminative action of the protective devices; as far as practicable the arrangements are also to secure the availability of other services;
(b) elimination of the fault to reduce damage to the system and hazard of fire;
(c) uninterrupted electrical supply during normal operation of the system including motor starting and similar transient over-current conditions.

4.1.2 Short-circuit and overload protection are to be provided in each non-earthed line of each system of supply and distribution, unless exempted under the provisions of any paragraph in this Section.

4.1.3 The protection of circuits is to be such that a fault in a circuit does not cause the interruption of supplies used to provide emergency, Mobility systems or Ship Type systems other than those dependent on the circuit where the fault occurred. For circuits used to provide Mobility or Ship Type systems which need not necessarily be in continuous operation to maintain propulsion and steering but which are necessary for maintaining the vessel’s safety, arrangements that ensure that a fault in a circuit does not cause the sustained interruption of supply to healthy circuits may be accepted. Such arrangements are to ensure the supply to healthy circuits is automatically re-established in sufficient time after a fault in a circuit.

4.1.4 Protection systems are to be developed using a systematic design procedure incorporating verification and validation methods to ensure successful implementation of the requirements above. Details of the procedures used are to be submitted when requested. An approved copy of the details required by *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.6* and *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.7* is to be retained on board and made available to the LR Surveyor on request. Access to protection relays is to be restricted, such that they will generally only be adjusted by authorised personnel to avoid incorrect operation.

4.1.5 Short circuit protection is to be provided for each source of power and at each point at which a distribution circuit branches into two or more subsidiary circuits.

4.1.6 Where protection for generator power circuits is provided at the associated switchboard, the cabling between generator and switchboard is to be of a type, and installed in a manner such as to minimise the risk of short-circuit.

4.1.7 Protection for battery circuits is to be provided at a position external and adjacent to the battery compartments. Where arrangements comply with *Vol 2, Pt 9, Ch 2, 7.3 Location 7.3.5*, the protection may be installed at a suitable location in the battery compartment.

4.1.8 Protection may be omitted from the following:

(a) Engine-starting battery circuits.

(b) Circuits for which it can be shown that the risk resulting from spurious operation of the protective device may be greater than that resulting from a fault.

4.1.9 Short circuit protection may be omitted from cabling or wiring to items of equipment internally protected against short-circuit or where it can be shown that they are unlikely to fail to a short-circuit condition and where the cabling or wiring is installed in a manner such as to minimise the risk of short circuit.

4.1.10 Overload protection may be omitted from the following:

(a) one line of circuits of the insulated type;
(b) circuits supplying equipment incapable of being over-loaded, or overloading the associated supply cable, under normal conditions, and unlikely to fail to an overload condition.

4.2 Protection against short-circuit

4.2.1 Protection against short-circuit currents is to be provided by circuit-breakers or fuses.

4.2.2 The rated short circuit making and breaking capacity of every protective device is to be adequate for the prospective fault level at its point of installation; the requirements for circuit breakers and fuses are detailed in *Vol 2, Pt 9, Ch 4, 4.5 Circuit-breakers* and *Vol 2, Pt 9, Ch 4, 4.6 Fuses* respectively.

4.2.3 The prospective fault current is to be calculated for the following set of conditions:

(a) all generators, motors and, where applicable, all transformers, connected as far as permitted by any interlocking arrangements.
(b) a fault of negligible impedance close up to the load side of the protective device.

4.2.4 In the absence of precise data, the prospective fault current may be taken to be:

(a) for alternating current systems at the main switchboard:

10 x f.l.c. (rated full load current) for each generator that may be connected, or, if the subtransient direct axis reactance, *X"d* , of each generator is known,

$\frac{f.l.c}{X''d(p.u.)}$ for

each generator, and 3 x f.l.c. for motors simultaneously in service.

The value derived from the above is an approximation to the r.m.s. symmetrical fault current; the peak asymmetrical fault current may be estimated to be 2,5 times this figure (corresponding to a fault power factor of approximately 0,1).

(b) battery-fed direct current systems at the battery terminals:

(i) 15 times ampere hour rating of the battery for vented lead-acid cells, or of alkaline type intended for discharge at low rates corresponding to a battery duration exceeding three hours; or
(ii) 30 times ampere hour rating of the battery for sealed lead-acid cells having a capacity of 100 Ampere hours or more, or of alkaline type intended for discharge at high rates corresponding to a battery duration not exceeding three hours; and
(iii) 6 x f.l.c. for motors simultaneously in service (if applicable).

4.3 Protection against overload

4.3.1 The characteristics of protective devices provided for overload protection are to ensure that cabling and electrical machinery is protected against overheating resulting from mechanical or electrical overload.

4.3.2 Fuses of a type intended for short-circuit protection only (e.g. high-voltage fuses or fuses complying with IEC 60269-1: *Low-voltage fuses – Part 1: General requirements*, of type ‘a’) are not to be used for overload protection.

4.4 Protection against earth faults

4.4.1 Every distribution system that has an intentional connection to earth, by way of an impedance, is to be provided with a means to continuously monitor and indicate the current flowing in the earth connection.

4.4.2 If the current in the earth connection exceeds 5 A there is to be an alarm and the fault current is to be automatically interrupted or limited to a safe value.

4.4.3 The rated short circuit capacity of any device used for interrupting earth fault currents is to be not less than the prospective earth fault current at its point of installation.

4.4.4 Insulated neutral systems with harmonic distortion of the voltage waveform, which may result in earth fault currents exceeding the level given in *Vol 2, Pt 9, Ch 4, 4.4 Protection against earth faults 4.4.2* because of capacitive effects, are to be provided with arrangements to isolate the faulty circuit(s).

4.5 Circuit-breakers

4.5.1 Circuit-breakers for alternating current systems are to satisfy the following conditions:

(a) the r.m.s. symmetrical breaking current for which the device is rated is to be not less than the r.m.s. value of the a.c. component of the prospective fault current, at the instant of contact separation (i.e. first half cycle, or time of interruption where an intentional time delay is provided to ensure suitability);
(b) the peak asymmetrical making current for which the device is rated is not to be less than the peak value of the prospective fault current at the first half cycle, allowing for maximum asymmetry;
(c) the power factor at which the device short circuit ratings are assigned is to be no greater than that of the prospective fault current; alternatively for high voltage, the rated percentage d.c. component of the short-circuit breaking current of the device is to be not less than that of the prospective fault current.

4.5.2 Circuit-breakers for d.c. systems are to have a breaking current not less than the initial prospective fault current. The time constant of the fault current is not to be greater than that for which the circuit-breaker was tested.

4.5.3 The fault ratings considered in *Vol 2, Pt 9, Ch 4, 4.5 Circuit-breakers 4.5.1* and *Vol 2, Pt 9, Ch 4, 4.5 Circuit-breakers 4.5.2*, are to be assigned on the basis that the device is suitable for further use after fault clearance.

4.5.4 Circuit-breakers selection is, and ratings are, to be in accordance with the relevant requirements of IEC 60092- 202: *Electrical installations in ships – Part 202: System design* Alternative methods acceptable to LR of selecting suitable circuit-breakers may be considered.

4.6 Fuses

4.6.1 Fuses for a.c.systems are to have a breaking current rating not less than the initial r.m.s. value of the a.c. component of the prospective fault current.

4.6.2 Fuses for d.c. systems are to have a d.c. breaking current rating not less than the initial value of the prospective fault current.

4.7 Circuit-breakers requiring back-up by fuse or other device

4.7.1 The use of a circuit-breaker having a short-circuit current capacity less than the prospective short-circuit current at the point of installation is permitted, provided that it is preceded by a device having at least the necessary short-circuit capacity. The generator circuit breakers are not to be used for this purpose.

4.7.2 The same device may back-up more than one circuit-breaker provided that no Mobility systems, Ship Type systems, or emergency service is supplied from there, or that any such service is duplicated by arrangements unaffected by tripping of the device.

4.7.3 The combination of back-up device and circuitbreaker is to have a short-circuit performance at least equal to that of a single circuit-breaker satisfying the requirements of *Vol 2, Pt 9, Ch 4, 4.5 Circuit-breakers*

4.7.4 Evidence of testing of the combination is to be submitted for consideration; alternatively, consideration may be given to arrangements where it can be shown that:

(a) the takeover current, above which the back-up device would clear a fault, is not greater than the rated shortcircuit breaking capacity of the circuit-breaker; and
(b) the characteristics of the back-up device, and the prospective fault level, are such that the peak fault current rating of the circuit-breaker cannot be exceeded; and
(c) the Joule integral of the let-through current of the back-up device does not exceed that corresponding to the rated breaking current and opening time of the circuit-breaker.

4.8 Protection of generators

4.8.1 The protective gear required by *Vol 2, Pt 9, Ch 4, 4.8 Protection of generators 4.8.2* and *Vol 2, Pt 9, Ch 4, 4.8 Protection of generators 4.8.3* is to be provided as a minimum.

4.8.2 Generators not arranged to run in parallel are to be provided with a circuit-breaker arranged to open simultaneously, in the event of a short-circuit, an overload or an under-voltage, all insulated poles. In the case of generators rated at less than 50 kW, a multipole linked switch with a fuse, complying with *Vol 2, Pt 9, Ch 4, 4.3 Protection against overload 4.3.2*, in each insulated pole will be acceptable.

4.8.3 Generators arranged to operate in parallel are to be provided with a circuit-breaker arranged to open simultaneously, in the event of a short-circuit, an overload or an under-voltage, all insulated poles. This circuit-breaker is to be provided with reverse power protection with time delay, selected or set within the limits of 2 per cent to 15 per cent of full load to a value fixed in accordance with the characteristics of the prime mover. A fall of 50 per cent in the applied voltage is not to render the reverse power mechanism inoperative, although it may alter the amount of reverse power required to open the breakers.

4.8.4 The generator circuit-breaker short circuit and overload tripping arrangements, or fuse characteristics, are to be such that the machine's thermal withstand capability is not exceeded.

4.8.5 All high-voltage generators and low-voltage generators having a capacity of 1500 kVA or above are to be equipped with a protective device which, in the event of a short-circuit in the generator or in the cables between the generator and its circuit-breaker, will instantaneously open the circuit breaker and de-excite the generator.

4.8.6 The voltage and time delay settings of the undervoltage release mechanism(s) required by*Vol 2, Pt 9, Ch 4, 4.8 Protection of generators 4.8.2* and *Vol 2, Pt 9, Ch 4, 4.8 Protection of generators 4.8.3* are to be chosen to ensure that the discriminative action required by *Vol 2, Pt 9, Ch 4, 4.1 General 4.1.1*is maintained.

4.8.7 The protection of electrical power generation and distribution systems is to be so arranged that, in the event of failure of a protection device, including integrated multifunction relays, sufficient power can be supplied to all Mobility and/or Ship Type systems, *see also Vol 2, Pt 9, Ch 3, 4.2 Essential services 4.2.4*.

4.8.8 It is to be possible to control the generator prime mover in the event of failure of an electrical system protection device.

4.9 Load management

4.9.1 Arrangements are to be made to disconnect automatically sufficient load to reduce the load when the generator(s) is/are overloaded. Appropriate time delays are to be provided in these load reduction arrangements.

4.9.2 Arrangements are also to be made such that, where applicable, the maximum load that can be applied to generators driven by prime movers is not in excess of that determined by *Vol 2, Pt 2, Ch 1, 9.3 Auxiliary engine governors 9.3.2* and *Vol 2, Pt 2, Ch 2, 7.3 Containment 7.3.4*.

4.9.3 If required, this load switching may be carried out in one or more stages, in which case circuits other than Mobility or Ship Type systems are to be included in the first group to be disconnected.

4.9.4 The load management of power systems supplying electric propulsion motors is to satisfy the requirements of *Vol 2, Pt 4, Ch 5, 4.3 Power requirements*.

4.9.5 Consideration is to be given to providing means to inhibit automatically the starting of large motors, or the connection of other large loads, until sufficient generating capacity is available to supply them.

4.10 Feeder circuits

4.10.1 Isolation and protection of each feeder circuit is to be ensured by a multiple circuit-breaker or linked switch with a fuse in each insulated conductor. Protection is to be in accordance with *Vol 2, Pt 9, Ch 4, 4.2 Protection against short-circuit* and *Vol 2, Pt 9, Ch 4, 4.3 Protection against overload*. The protective devices are to allow excess current to pass during the normal accelerating period of motors.

4.11 Motor circuits

4.11.1 Motors of rating exceeding 0,5 kW and all motors for Mobility or Ship Type systems are to be protected individually against overload and short circuit. Motors for Mobility or Ship Type systems for the safety and propulsion of the ship and which are duplicated are to be provided with arrangements to start the standby motor and disconnect the faulty motor. Such motors may have an overload alarm instead of overload protection. The actions to start the standby motor and disconnect the faulty motor may be carried out by suitably trained personnel but in ships with **UMS** notation the arrangements are to be automatic.

4.11.2 Protection for both the motor and its supply cable may be provided by the same device, provided that due account is taken of any differences between ratings of cable and motor.

4.11.3 Where operation of an item of equipment is dependent upon a number of motors, consideration may be given to the provision of a common means of short circuit protection.

4.11.4 The characteristics of the arrangements for overload protection of motors are to be selected in relation to both the starting and normal rated conditions that are to include any load factors of intermittent service motors.

4.11.5 Where fuses are used to protect polyphase motor circuits, means are to be provided to protect the motor from unacceptable overcurrent in the case of single phasing.

4.12 Protection of transformers

4.12.1 Short circuit protection for transformers is to be provided by circuit breakers or fuses in the primary circuit and in addition, overload protection is to be provided either in the primary or secondary circuit.

4.12.2 Arrangements are to be made to prevent the primary windings of transformers being inadvertently energised from their secondary side when disconnected from their source of supply.

4.13 Harmonic filters

4.13.1 Harmonic filters' final sub-circuits are to be protected individually against overload and short-circuit.

4.13.2 An alarm is to be initiated in the event of protective device operation.

4.13.3 Where parallel harmonic filters are used, an alarm is to be initiated in the event of current imbalance that could lead to failure of a harmonic filter.

■ *Section 5*
Protection from electric arc hazards within electrical equipment

5.1 General

5.1.1 An assessment is to be carried out in accordance with *Vol 2, Pt 9, Ch 4, 5.2 Hazard identification and assessment 5.2.1* for all electrical equipment within which an arcing fault could occur, such as:

- harmonic filters;
- motor starter panels;
- semiconductor converters;
- switchboards, section boards and distribution boards;
- transformers.

5.2 Hazard identification and assessment

5.2.1 An assessment is to be carried out to identify the hazards and their consequences for personnel resulting from electric arcs within the electrical equipment identified in *Vol 2, Pt 9, Ch 4, 5.1 General 5.1.1*. The purpose of the assessment is to demonstrate that the design incorporates adequate measures to reduce the risk of injury to personnel should an arcing fault occur within the electrical equipment, and that this will help to ensure both personnel and ship safety.

Details of the following are to be submitted:

(a) each task to be performed, e.g. switching, equipment maintenance, instrument observation or cleaning;
(b) the hazards to personnel that could result from an electric arc occurring during each task, and the hazards to personnel that could result from the electric arc;
(c) the methods to be used to help to prevent electric arcs;
(d) the methods to be used to protect personnel from hazards resulting from electric arcs within electrical equipment.

5.3 Calculations to be submitted

5.3.1 The following calculations are to be conducted and used in the hazard identification and assessment:

(a) Calculations of the maximum current that would flow through an electric arc between each conductor and its adjacent conductor, and between each conductor and the exposed conductive parts of the enclosure, in the case of an arcing fault;

(b) The maximum incident energy at the intended working distance in the case of an arcing fault;

(c) The distance from each conductor at which the incident energy would be 5 Joules per centimetre squared in the case of an arcing fault when the enclosure door is open.

These calculations may be made in accordance with IEEE Standard 1584, *IEEE Guide for Performing Arc-Flash Hazard Calculations*, or another relevant Standard acceptable to LR.

5.4 Testing and trials

5.4.1 It is to be demonstrated that, where provided, arrangements to detect arcing faults function correctly.

■ *Section 6*
Protection of electrical equipment against the effects of lightning strikes

6.1 General

6.1.1 Precautions are to be taken to protect Mobility and/or Ship Type systems electronic equipment that may be susceptible to damage from voltage pulses attributable to the secondary effects of lightning. This may be achieved by suitable design and/or the use of additional protective devices, such as surge arrestors. Resultant induced voltages may be further reduced by the use of earthed metallic screened cables.

6.1.2 In order to minimise the risks of damage to the ship and its electrical installation due to lightning, ships are to be provided with lightning protective arrangements in accordance with the applicable requirements of IEC 60092-401 *Electrical installations in ships. Part 401: Installation and test of completed installation* or an alternative and relevant National Standard.

■ Scope

This Chapter details the requirements for installations and equipment selection to minimise the risk of ignition of explosive gas or dust atmospheres.

Application of this Chapter will facilitate the verification of the performance requirements of *ANEP-77 NATO Naval Ship Code*, Chapter IV, Regulation 18.

■ *Section 1*
Functional requirements

1.1 Functional requirements

1.1.1 The design, selection and installation of mechanical and electrical equipment for use in explosive gas or dust atmospheres are to be such as to minimise the sources of ignition.

■ *Section 2*
Performance requirements

2.1 Performance requirements

2.1.1 In order to facilitate the proper selection and installation of equipment to be used safely in areas where explosive gas or dust atmospheres may occur, such dangerous or hazardous areas are to be identified in accordance with an acceptable National or International Standard.

2.1.2 Hazardous areas shall be divided into zones in accordance with a National or International Standard agreed by the Naval Administration.

2.1.3 Electrical equipment or wiring shall not be installed in hazardous areas unless essential for operational purposes or safety enhancement.

2.1.4 Where electrical or mechanical equipment is installed in hazardous areas, it shall be of a type suitable for the environment in which it will be operated. Equipment shall be selected, installed and maintained in accordance with National or International Standards. Equipment for hazardous areas shall be evaluated and certified by an accredited testing authority or notified body recognised by the Naval Administration.

2.1.5 Where machinery is operated in a potentially flammable atmosphere, a means is to be provided to detect any abnormal parameters which may lead to ignition of the atmosphere.

2.1.6 Any failure that can change the categorisation of a hazardous area shall be indicated by an alert.

2.1.7 The integrity of the boundary of the hazardous area shall be such as not to compromise the safety of the adjacent space.

2.1.8 Suitable indication of the nature of the potential hazards shall be provided at the entrance(s) to the space, and on the equipment where applicable.

■ *Section 3*
Verification requirements

3.1 General

3.1.1 Compliance with the requirements in *Vol 2, Pt 9, Ch 5, 4 Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts* is deemed to satisfy the functional requirements and performance requirements above.

3.1.2 Where a designer offers a novel solution, an engineering safety and justification report is to be submitted. The engineering safety and justification report is to demonstrate how the proposed solution will satisfy the functional requirements and performance requirements in *Vol 2, Pt 9, Ch 5, 1 Functional requirements*.

3.1.3 The Naval Administration may impose requirements additional to those in this Chapter.

■ *Section 4*
Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts

4.1 General

4.1.1 The installation of electrical equipment in spaces and locations in which flammable mixtures are liable to collect, e.g. areas containing flammable gas or vapour and/or combustible dust, is to be minimised as far as is consistent with operational necessity and the provision of lighting, monitoring, alarm or control facilities enhancing the overall safety of the ship.

4.1.2 In order to eliminate potential sources of ignition from spaces and locations in which flammable mixtures are liable to collect, such dangerous or hazardous areas are to be identified and electrical equipment within these areas is to be selected and installed in accordance with the requirements of this Section.

4.1.3 Electrical installations in magazines, are to be in accordance with *Vol 1, Pt 4, Ch 1, 6.8 Piping, cabling and electrical systems*

4.1.4 Equipment that is to be installed in an area where both explosive gases and combustible dusts can be present is to be selected in accordance with both *Vol 2, Pt 9, Ch 5, 4.2 Selection of equipment for use in explosive gas atmospheres* and *Vol 2, Pt 9, Ch 5, 4.3 Selection of equipment for use in the presence of combustible dusts*.

4.1.5 For permanent secondary battery installations, *see Vol 2, Pt 9, Ch 2, 7 Batteries*.

4.2 Selection of equipment for use in explosive gas atmospheres

4.2.1 When equipment is to be installed in areas where an explosive gas atmosphere may be present it is generally to be of a type providing protection against ignition of the gases encountered and compliant with the relevant Parts of IEC 60079: *Explosive atmospheres*, an agreed specified standard where applicable, *see Vol 2, Pt 9, Ch 5, 4.2 Selection of equipment for use in explosive gas atmospheres 4.2.4*, *Vol 2, Pt 9, Ch 5, 4.2 Selection of equipment for use in explosive gas atmospheres 4.2.5* or *Vol 2, Pt 9, Ch 5, 4.2 Selection of equipment for use in explosive gas atmospheres 4.2.6*.

4.2.2 The equipment protection type permitted depends on the hazardous zone where the equipment is to be located, as defined in *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces*. For certain locations on the ship other requirements may limit installations to specific equipment types and/or particular applications.

4.2.3 Equipment for **zone 0** or **zone 1**, with the exception of simple apparatus as defined in *Vol 2, Pt 9, Ch 5, 4.2 Selection of equipment for use in explosive gas atmospheres 4.2.4* or *Vol 2, Pt 9, Ch 5, 4.2 Selection of equipment for use in explosive gas*

atmospheres 4.2.5, is to be certified or approved by a National or other appropriate Authority. Equipment without independent certification or approval may be considered for installation in **zone 2**.

4.2.4 In **zone 0**, the following may be considered:

(a) intrinsically safe, category ‘a’ (Ex ‘ia’); or

(b) simple electrical apparatus and components (for example, thermocouples, photocells, strain gauges, junction boxes, switching devices), included in intrinsically safe circuits of category ‘ia’, not capable of storing or generating electrical power or energy in excess of the limits given in IEC 60079-14: *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*.

4.2.5 In **zone 1**, the following may be considered:

(a) apparatus permitted within **zone 0**;

(b) intrinsically safe, category ‘b’ (Ex ‘ib’);

(c) simple apparatus as defined above, included in intrinsically safe circuits of category ‘ib’;

(d) increased safety (Ex ‘e’);

(e) flameproof (Ex ‘d’);

(f) pressurised enclosure (Ex ‘p’);

(g) powder filled (Ex ‘q’); or

(h) encapsulated (Ex ‘m’);

(i) Special – Ex ‘s’, where permitted by the equipment certification.

4.2.6 In **zone 2**, the following may be considered:

(a) apparatus permitted within **zone 0** or **zone 1**;

(b) type of protection ‘n’ or ‘N’;

(c) equipment such as control panels, protected by purging and pressurisation and capable of being verified by inspection as meeting the requirements of IEC 60079-2: *Explosive atmospheres – Part 2: Equipment protection by pressurized enclosures "p"*; or

(d) radio aerials having robust construction, meeting the relevant requirements of IEC 60079-15: *Explosive atmospheres – Part 15: Equipment protection by type of protection "n"*. Additionally, in the case of transmitter aerials, it is to be shown, by detailed study or measurement, or by limiting the peak radiated power and field strength to 1 W and 30 V/m, respectively, that they present negligible risk of inducing incendive sparking in adjacent structures or equipment.

4.2.7 Apparatus having type of protection ‘ia’, ‘ib’, or ‘d’, is to be of a Group (IIA, IIB or IIC) meeting or exceeding that required for safe operation in the presence of any gas or vapour that can be present, or is to be certified specifically for such gases or vapours.

4.2.8 All apparatus is to be of a temperature classification (T1 to T6) that confirms, or is to be assessed so as to confirm, that its maximum surface temperature will not reach the ignition temperature of any gas or vapour, or mixture of gases or vapours, which can be present. The surface temperature considered may be that of an internal or external part, according to the type of protection of the apparatus.

4.3 Selection of equipment for use in the presence of combustible dusts

4.3.1 Where apparatus is to be installed in **hazardous areas**, as defined by *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.3*, associated with the presence of combustible dusts, it is, when practicable, to be of a type certified or approved by a National or other appropriate Authority for the dusts and, additionally, any explosive gases encountered.

4.3.2 Electrical equipment for use in such **hazardous areas** is to be so designed and installed as to minimise the accumulation of dust which may interfere with the safe dissipation of heat from the enclosure.

4.3.3 Where apparatus is to be installed in **extended hazardous areas**, as defined by *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.3*, associated with the presence of combustible dust, the following may be considered:

(a) apparatus permitted within a hazardous area associated with the combustible dust(s) that can be present;

(b) apparatus having degree of protection IP5X, or better, and having a surface temperature under normal operating conditions not exceeding the auto-ignition temperature of the dust(s) that can be present; and

(c) apparatus of a type which ensures absence of sparks or arcs and hot spots during normal operation.

4.3.4 Where equipment certified for combustible dusts is not available, consideration will be given to the use of apparatus complying, as a minimum, with the following requirements provided no explosive gases will be present:

(a) the enclosure is to be at least dust protected (IP5X) having, when type tested, an ingress of fine dust within the enclosure not exceeding 10 g per m^3 of free air space; and
(b) the surface temperature of the apparatus, under the most onerous combination of normal operating conditions, but in the absence of a dust layer, is not to exceed two-thirds of the minimum ignition temperature in degrees Celsius of the dust/air mixture(s) that can be present; or
(c) the equipment is to be certified intrinsically safe having a temperature classification ensuring compliance with (b); or
(d) pressurised and operated in accordance with procedures ensuring, prior to its re-energisation, the absence of dust within the enclosure following loss of pressurisation and consequent shutdown, and having surface temperature complying with (b); or
(e) simple apparatus included in intrinsically safe circuits or radio aerials, complying with *Vol 2, Pt 9, Ch 5, 4.2 Selection of equipment for use in explosive gas atmospheres 4.2.4*, *Vol 2, Pt 9, Ch 5, 4.2 Selection of equipment for use in explosive gas atmospheres 4.2.5* or *Vol 2, Pt 9, Ch 5, 4.2 Selection of equipment for use in explosive gas atmospheres 4.2.6* respectively.

4.3.5 Consideration may also be given to arrangements complying with IEC 60092-506: *Electrical installation in ships – Part 506: Special features: Ships carrying specific dangerous goods and materials hazardous only in bulk*.

4.4 Installation of electrical equipment

4.4.1 The method of installation and application of electrical equipment suitable for use in explosive gas atmospheres or in the presence of combustible dusts is to be in accordance with IEC 60079-14: *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*, or the National Code of Practice relevant to the Standard with which the equipment complies. The ambient temperature range for which the apparatus is certified is to be taken to be –20°C to 40°C, unless otherwise stated, and account is to be taken of this when assessing the suitability of the equipment for the auto-ignition temperature of the gases and dusts encountered. Any special requirements laid down by the equipment certification documentation are also to be observed.

4.4.2 All switches and protective devices from which equipment located in hazardous zones or spaces is supplied are to interrupt all poles or phases and, where practicable, are to be located in a non-hazardous zone or space. Such equipment, switches and protective devices are to be suitably labelled for identification purposes.

4.5 Hazardous zones and spaces

4.5.1 For hazardous zones or spaces and sources of hazard for naval ships, the following principles are to apply in general.

4.5.2 Hazardous areas associated with flammable liquids or gases are classified into zones based upon the frequency of the occurrence and duration of an explosive gas atmosphere, as follows:

- **zone 0**: place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is present continuously or for long periods or frequently;
- **zone 1**: place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally;
- **zone 2**: place in which an explosive atmosphere consisting of a mixture with air of flammable substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

See IEC 60079-101-1: *Explosive atmospheres – Part 10-1: Classification of areas – Explosive gas atmospheres.*.

4.5.3 Hazardous areas associated with solid substances or packaged liquids are classified into zones based upon the frequency of the occurrence and duration of an explosive atmosphere due to the presence of gas and/or dust, as follows:

- **hazardous area**: area in which an explosive atmosphere is likely to occur in normal operation (comparable with **zone 1**)
- **extended hazardous area**: area in which an explosive atmosphere is not likely to occur in normal operation and, if it does occur, is likely to do so only infrequently and will exist for a short period only (comparable with **zone 2**).

See IEC 60079-10-2:*Explosive atmospheres-Part 10-2: Classification of areas – Combustible dust atmospheres, or IEC 60092-506: Electrical Installation in ships-Part 506 – Special features – Ships carrying specific dangerous goods and materials hazardous only in bulk.*. An explosive atmosphere may exist due to gas and/or dust.

4.5.4 A hazardous zone or space may arise from the presence of any of the following:

(a) spaces or tanks containing either:
   (i) flammable liquid having a flashpoint (closed-cup test) not exceeding 60°C;

(ii) flammable liquid having a flashpoint exceeding 60°C, heated or raised by ambient conditions to a temperature within 15°C of its flashpoint; or

(iii) flammable gas;

(b) piping systems or equipment containing fluid defined by (a) and having flanged joints or glands or other openings through which leakage of fluid may occur under normal operating conditions;

(c) spaces containing solids, such as coal or grain, liable to release flammable gas and/or combustible dust;

(d) spaces containing dangerous goods in packaged form, of the following Classes as defined in the IMDG Code: 1 (with the exception of goods in division 1.4, compatibility group S), 2.1 (inclusive of applicable gas bottles for on board use), 3, 6.1 and 8;

(e) piping systems or equipment associated with processes (such as electrochlorination) generating flammable gas as a by-product and having openings from which the gas may escape under normal operating conditions; or

(f) piping systems or equivalent containing flammable liquids not defined by (a), having flanged joints, glands or other openings through which leakage of fluid in the form of a mist or fine spray may occur under normal operating conditions.

4.5.5 The following zones or spaces are regarded as hazardous, **zone 0**:

(a) the interiors of those spaces, tanks, piping systems and equipment defined by *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.4* and *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.4*; and

(b) enclosed, unventilated spaces containing pipework or equipment defined by *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.4* and *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.4*.

4.5.6 The following zones or spaces are regarded as hazardous, **zone 1**:

(a) the interiors of spaces containing dangerous goods as defined by *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.4*;

(b) unventilated spaces separated by a single bulkhead or deck from a cargo defined by *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.4*;

(c) ventilated spaces containing pipework or equipment defined by *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.4* and *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.4*;

(d) zones within a 1,5 m radius of ventilation outlets, hatches or doorways or other openings into spaces defined by *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.6*, *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.6* or *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.6*, or within 1,5 m of the ventilation outlets of spaces regarded by *Vol 2, Pt 9, Ch 5, 4.7 Ventilation* as open areas and which contain the pipework or equipment defined by *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.4* or *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.4*. Where the hazard results from flammable gas or vapour having a density relative to that of air of more than 0,75 m, the hazardous zone is considered to extend vertically downward to solid deck, or for a distance of 9 m, whichever is the lesser;

(e) zones within a 1,5 m radius of flanged joints, or glands or other openings defined by *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.4*; in the case of gas or vapour having a relative density of more than 0,75 m, the hazardous zone is considered to extend vertically downwards as described under *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.6*;

(f) zones within a 1,5 m radius of flanged joints, or glands or other openings defined by *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.4* and *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.4*;

(g) zones within a 1,5 m radius of bunds or barriers intended to contain spillage of liquids defined by *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.4*;

(h) zones on open deck within a 1,5 m radius of any opening into a space defined by *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.6* or *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.6*; and

(i) enclosed or semi-enclosed spaces with direct opening into a **zone 1** hazardous location.

4.5.7 The following zones or spaces are regarded as hazardous, **zone 2**:

(a) ventilated spaces separated by a single bulkhead or deck from a **zone 0** space;

(b) zones on open deck extending 1,5 m beyond those defined by *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.6*, *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.6*, *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.6*, *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.6* or *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.6*;

(c) zones within a 1,5 m radius of ventilation inlets serving spaces defined by *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.6* or *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.6*; and

(d) enclosed or semi-enclosed spaces with direct opening into a **zone 2** hazardous location.

4.6 Semi-enclosed spaces

4.6.1 Semi-enclosed spaces are considered to be spaces limited by decks and/or bulkheads in such a manner that the natural conditions of ventilation are sensibly different from those obtained on open deck.

4.7 Ventilation

4.7.1 Where an enclosed or semi-enclosed space is provided with mechanical ventilation ensuring at least 12 air changes/ hour, and leaving no areas of stagnant air, it may be regarded in consideration of hazardous zones as would otherwise be defined by *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.5*, *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.6* or *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.6* and *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.7*, as an open area.

4.7.2 Where the rate of ventilation air flow, in relation to the maximum rate of release of flammable substances reasonably to be expected under normal conditions, is sufficient to prevent the concentration of flammable substances approaching their lower explosive limit, consideration may be given to regarding as non hazardous, the space, ventilation and other openings into it, and the zone around the equipment contained within.

4.7.3 An alarm is to be provided on the navigating bridge and the engine control room to indicate any loss of the required ventilation capacity. Initiation of an alarm by a fan motor running or fan rotation monitoring device will not normally satisfy this requirement.

4.8 Pressurisation

4.8.1 A space having access to a hazardous space or zone defined as **zone 1** or **zone 2** may be regarded as non-hazardous if fulfilling all the following conditions:

(a) access is by means of an air-lock, having gastight steel doors, the inner of which, as a minimum, is self-closing without any hold-back arrangement;
(b) it is maintained at an overpressure relative to the external hazardous area by ventilation from a non-hazardous area;
(c) the relative air pressure within the space is continuously monitored and so arranged that, in the event of loss of overpressure, an alarm is given and the electrical supply to all equipment not of a type suitable for zone 1 is automatically disconnected. Where the shutdown of equipment could introduce a hazard, an alarm may be given, in lieu of shutdown, upon loss of overpressure, and a means of disconnection of electrical equipment not of a type suitable for **zone 1**, capable of being controlled from an attended station, provided in conjunction with an agreed operational procedure; where the means of disconnection is located within the space then it is to be effected by equipment of a type suitable for **zone 1**;
(d) any electrical equipment required to operate upon loss of overpressure, lighting fittings (*see Vol 2, Pt 9, Ch 6, 4.3 Lighting circuits 4.3.3*) and equipment within the air-lock, is to be of a type suitable for **zone 1**; and
(e) means are to be provided to prevent electrical equipment, other than of a type suitable for **zone 1**, being energised until the atmosphere within the space is made safe, by air renewal of at least 10 times the capacity of the space.

4.8.2 A space having access to a hazardous space or zone defined as **zone 2** may be regarded as non-hazardous if fulfilling all the following conditions:

(a) access is by means of a self-closing gastight steel door without any hold-back arrangement;
(b) it is maintained at an overpressure, relative to the external hazardous area by ventilation from a non-hazardous area;
(c) the relative air pressure within the space is continuously monitored and so arranged that, in the event of loss of overpressure, an alarm is given. A means of disconnection of electrical equipment not of a type suitable for **zone 2** is to be provided; where the means of disconnection is located within the space then it is to be effected by equipment of a type suitable for **zone 2**;
(d) any electrical equipment required to operate upon loss of overpressure (e.g. lighting fittings, *see Vol 2, Pt 9, Ch 7, 4.7 Valve control and indication systems 4.7.3*), is to be of a type suitable for **zone 2**.

4.9 Cable and cable installation

4.9.1 Electric cables are not, as far as is practicable, to be installed in hazardous zones or spaces, except where serving equipment installed within the zone or space. Through runs of cable may be accepted in locations classified as **zone 1** or **zone 2**, where alternative routes are impracticable.

4.9.2 In addition to the requirements of *Vol 2, Pt 9, Ch 3, 8 Electric cables, optical fibre cables and busbar trunking systems (busways)* , cables for circuits that are not intrinsically safe, which are located in hazardous zones or spaces, or which may be exposed to cargo oil, oil vapour or gas, are to be either:

(a) mineral insulated with copper sheath; or

(b) armoured or braided for earth detection; or

(c) otherwise adequately protected against mechanical or chemical damage, within **zone 2** or non-hazardous locations only; or

(d) as otherwise specifically permitted elsewhere within this Section.

4.9.3 Armouring, braiding and other metal coverings of cables installed in dangerous zones or spaces are to be effectively earthed at least at both ends, *see Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding 2.4.4*.

4.9.4 Where there is risk of intermittent contact between armour and exposed metalwork, non-metallic impervious sheath is to be applied over metallic armour of cables.

4.9.5 Cables associated with intrinsically safe circuits are to be used only for such circuits. They are to be physically separated from cables associated with non-intrinsically safe circuits, e.g. neither installed in the same protective casing nor secured by the same fixing clip. Consideration may be given to other arrangements complying with IEC 60079- 14: *Explosive atmospheres – Part 14 : Electrical installations design, selection and erection*.

4.9.6 In **zone 0**, cable joints may only be used in intrinsically safe circuits.

4.9.7 Cable runs in **zone 1** or **zone 2** are, where practicable, to be uninterrupted. Where discontinuities cannot be avoided, cable joints are, additionally, to:

- be made in an enclosure with a type of protection appropriate to the location; or
- provided the joint is not subject to mechanical stress, be epoxy filled, compound filled or sleeved with heatshrunk tubing, in accordance with the manufacturer's instructions.

4.10 Requirements for oil supply ships intended for the carriage in bulk of oil cargoes having a flash point not exceeding 60°C (closed-cup test)

4.10.1 In order to eliminate potential sources of ignition from hazardous areas on board Oil Supply Ships electrical equipment is to be selected and installed in accordance with IEC 60092: *Electrical installations in ships – Part 502: Tankers – Special features*.

4.10.2 The relevant group and temperature class for electrical equipment in hazardous zones are, respectively, IIA and T3.

4.10.3 Further to the requirements of paragraph *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.6*, open deck, or semi-enclosed spaces on open deck, within 3 m of the ventilation outlets of tanks defined in *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.4*, which permit the flow of small volumes of vapour or gas mixtures caused by thermal variation are to be regarded as hazardous **zone 1.**

4.10.4 Further to the requirements of paragraph *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.7*, open deck extending 2 m beyond those defined by *Vol 2, Pt 9, Ch 5, 4.5 Hazardous zones and spaces 4.5.6* are to be regarded as hazardous **zone 2**.

4.11 Special requirements for ships with spaces for carrying vehicles, helicopters and aircraft, with fuel in their tanks

4.11.1 Ships with closed spaces carrying vehicles, helicopter and aircraft with fuel having a flashpoint not exceeding 60ºC:

(a) except where exempted by (b) electrical equipment fitted within the space and within the exhaust ventilation trunking for the space is to be of a type acceptable for **zone 1**;

(b) where the ventilation system required by the Naval Administration is arranged to operate continuously and is sufficient to provide at least ten air changes per hour, whenever vehicles are on board, above a height of 45 cm from the vehicle deck, or any platform on which vehicles are carried, electrical equipment having an enclosure of ingress protection rating of at least IP 55 may be accepted as an alternative to that of a safe type;

(c) all electrical circuits terminating in the space are to be provided with multi-pole linked isolating switches located outside the space concerned. Provision is to be made for locking in the off position. This does not apply to safety circuits such as those for fire, smoke or gas detection.

■ Scope

The requirements of this Chapter are applicable to the design and construction philosophy for the lighting system.

This Chapter details the requirements for sub-systems and equipment within the boundary of the lighting system. Approval will be in respect of the integrity of the lighting system (including emergency and navigation lighting), configuration, EMC enclosure configuration (where appropriate), control, monitoring, alert and safety systems, and other critical support systems.

Application of this Chapter will facilitate the verification of the performance requirements of *ANEP-77 NATO Naval Ship Code*, Chapter IV, Regulations 11 and Chapter VII, Regulation 15.

■ *Section 1*
Functional requirements

1.1 Functional requirements

1.1.1 Illumination shall be provided appropriate for location and operational requirements in both normal and emergency conditions.

1.1.2 Lighting systems shall provide sufficient illumination to conduct any escape, evacuation and rescue activity during an emergency following loss of either main or emergency lighting

1.1.3 A Low Location Lighting system shall allow embarked persons to safely and effectively locate muster and evacuation stations.

■ *Section 2*
Performance requirements

2.1 Performance requirements

2.1.1 The siting of light fittings is to consider the transfer of heat to adjacent surfaces.

2.1.2 Illumination levels are to meet operational requirements.

2.1.3 System design intent of the lighting system is to permit the vessel to be operated in accordance with the CONOPS.

2.1.4 Main lighting systems are to provide a suitable level of illumination to allow:

(a) safe access to areas of the vessel that require it for normal operations;
(b) operation and control of the vessel.

2.1.5 The lighting systems are to be arranged such that a single failure will not cause total loss of illumination in any attended compartment.

2.1.6 In the event of loss of main lighting, at locations where illumination must be maintained for operational purposes, transitional lighting shall be provided. The transitional lighting is to be available for a period acceptable to the Naval Administration.

2.1.7 To meet operational requirements, lighting levels are to be controllable locally.

2.1.8 Operational lighting shall be provided in areas where there is an operational requirement for different levels of illumination from that provided by the main lighting system.

2.1.9 Emergency lighting shall provide sufficient illumination to locations essential for any Escape, Evacuation and Rescue.

2.1.10 The lighting system design intent shall:

(a) provide arrangements such that sufficient illumination is provided under foreseeable abnormal conditions to enable embarked persons to locate escape routes, escape exits, muster stations (if provided) and evacuation stations.
(b) enable emergency lighting to operate for a period as necessary to complete all Escape, Evacuation and Rescue activities.
(c) ensure that the emergency lighting has minimised susceptibility to damage.

2.1.11 System design intent of the navigational lights shall provide arrangements such that sufficient illumination is provided under normal and foreseeable abnormal conditions to enable the vessel to display the proper light configuration in compliance with the *International Regulations for Preventing Collisions at Sea* (COLREGS) in force.

■ *Section 3*
Verification requirements

3.1 General

3.1.1 Compliance with the requirements in *Vol 2, Pt 9, Ch 6, 4 Lighting systems* is deemed to satisfy the functional requirements and performance requirements above.

3.1.2 Where a designer offers a novel solution, an engineering safety and justification report is to be submitted. The engineering safety and justification report is to demonstrate how the proposed solution will satisfy the functional requirements and performance requirements in *Vol 2, Pt 9, Ch 6, 1 Functional requirements*.

3.1.3 The Naval Administration may impose requirements additional to those in this Chapter.

■ *Section 4*
Lighting systems

4.1 Lighting - General

4.1.1 The lighting systems are to be arranged such that a single failure will not cause total loss of illumination in any attended compartment.

4.1.2 In the event of loss of main lighting, at locations where illumination must be maintained for operational purposes, transitional lighting shall be provided until the main lighting is restored or emergency lighting is operational. The transitional lighting is to be available for a period acceptable to the Naval Administration.

4.1.3 To meet operational requirements, lighting levels are to be controllable locally.

4.1.4 Lamp holders, lamps and light fittings are to be in accordance with IEC 60092-306, *Electrical installations in ships – Part 306: Equipment – Luminaires and lighting accessories*.

4.1.5 Fittings, reactors, capacitors and other auxiliaries are not to be mounted on surfaces which are subject to high temperatures. If mounted separately they are additionally to be enclosed in an earthed conductive casing.

4.1.6 Where capacitors of 0,5 microfarads and above are installed, means are to be provided to promptly discharge the capacitors on disconnection of the supply.

4.2 Discharge lighting

4.2.1 Discharge lamps operating in excess of 250 V are only acceptable as fixed fittings. Warning notices calling attention to the voltage are to be permanently displayed at points of access to the lamps and where otherwise necessary.

4.3 Lighting circuits

4.3.1 Lighting circuits are to be supplied by final sub-circuits separate from those for heating and power. This does not preclude the supply from a lighting circuit supplying a single fixed appliance, such as a cabin fan, a dry shaver, a wardrobe or anti-condensation heater, taking a maximum current of 2 A.

4.3.2 Lighting for the following spaces is to be supplied from at least two final sub-circuits in such a way that failure of one of the circuits does not leave the space in darkness. One of these circuits may be an emergency circuit provided it is normally energised.

- Spaces that are required to be lit for the safe working of the ship, such as control stations, normal working spaces, etc.
- Spaces where there may be a hazard due to movement of crew, embarked personnel and/or equipment, such as in corridors, working passage ways, stairways leading to boat decks, crew and embarked personnel rooms, etc.
- Spaces where there may be a hazard due to moving machinery and hot parts, such as in machinery spaces, workshops, large galleys, laundries, etc.

4.3.3 Lighting for enclosed hazardous spaces is to be supplied from at least two final sub-circuits to permit light from one circuit to be retained while maintenance is carried out on the other. One of these circuits may be an emergency circuit, provided it is normally energised in which case the arrangements are to comply with *Vol 2, Pt 9, Ch 2, 5 Emergency and alternative sources of electrical power*.

4.3.4 Lighting of unattended spaces, such as store spaces, is to be controlled by multi-pole linked switches situated outside such spaces. Provision is to be made for the complete isolation of these circuits and locking the means of control in the off position.

4.3.5 For the design of lighting systems in magazines, weapon storage compartments and other dangerous spaces refer to *Vol 1, Pt 4, Ch 1, 6.8 Piping, cabling and electrical systems* and *Vol 2, Pt 9, Ch 5, 4 Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts*

4.4 Emergency lighting

4.4.1 For the purpose of this section emergency lighting, contingency lighting, transitional emergency lighting and supplementary emergency lighting are hereafter referred to under the generic name ‘emergency lighting’.

4.4.2 A fire or other casualty in a space containing a source of electrical power associated transforming (or converting) equipment or switchboard serving lighting, is not to render inoperative both main lighting and emergency lighting.

4.4.3 The illuminance provided by any one lighting circuit is to be adequate to permit safe evacuation in an emergency, having regard to the possible presence of smoke, *see Vol 2, Pt 9, Ch 2, 5.3 Starting arrangements*

4.4.4 The exit(s) from every main compartment occupied by crew and embarked personnel is to be continuously illuminated by an emergency lighting fitting.

4.4.5 Switches are not to be installed in the final sub-circuits to emergency light fittings unless the light fittings are serving normally unmanned spaces, (e.g. storage-rooms, cold rooms, etc.), or they are normally required to be extinguished for operational reasons, e.g. for night visibility from the navigating bridge. Where switches are fitted they are to be accessible only to ship's crew and embarked personnel with provision made to ensure that the emergency lighting is energised when such spaces are manned and/or during emergency conditions. Where ‘darken ship’ requirements are specified, switches may be installed in the circuits to emergency light fittings provided they are clearly identified.

4.4.6 Where emergency lighting fittings are connected to dimmers, provision is to be made, upon the loss of the main lighting, to automatically restore them to their normal level of illumination.

4.4.7 Fittings are to be specially marked to indicate that they form part of the emergency lighting system.

4.4.8 A means of illumination is to be provided in passageways and manned compartments for a period of at least four hours in the event of a failure of all main and emergency lighting. The provision of lanterns that operate automatically from a self contained power source on failure of the main and emergency lighting systems is the minimum acceptable arrangement.

4.5 Navigation lights

4.5.1 Navigation lights are to be connected separately to a distribution board reserved for this purpose only and accessible to the officer of the watch. This distribution board is to be connected to the emergency source of electrical power in compliance with, *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.7* and *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.9*. An alarm is to be activated in the event of failure of a power supply from the distribution board.

4.5.2 Each navigation light is to be controlled and protected in each insulated pole by a switch and fuse or circuit-breaker mounted on the distribution board.

4.5.3 Provision is to be made on the navigating bridge for the navigation lights to be transferred to an alternative circuit fed from the main source of electrical power. *See also Vol 2, Pt 9, Ch 2, 5.1 General 5.1.4*.

4.5.4 Each navigation light is to be provided with an automatic indicator giving audible and/or visual indication of failure of the light. If an audible device alone is fitted, it is to be connected to an independent source of supply, e.g. a battery, with means provided to test this supply. If a visual signal is used connected in series with the navigation light, means are to be provided to prevent extinction of the navigation light due to failure of the signal. The requirements of this paragraph do not apply to small vessels.

4.5.5 For navigation lights using light emitting diodes (consisting of multiple light sources) means to ensure that the overall luminous intensity of the navigation light is sufficient are to be provided in addition to the alarm to indicate the complete loss of the navigation light illumination required by *Vol 2, Pt 9, Ch 7, 4.7 Valve control and indication systems 4.7.4*. For replacement navigation lights, *see Vol 2, Pt 9, Ch 1, 1.7 Alterations and additions 1.7.7*.

4.5.6 To satisfy *Vol 2, Pt 9, Ch 7, 4.7 Valve control and indication systems 4.7.5*, an audible and visual alarm is to be activated to notify the bridge Officer of the Watch when the luminous intensity of the light reduces below the level required by the IMO *Convention on the International Regulations for Preventing Collisions at Sea*. Alternative measures to ensure continuing acceptable performance of navigation lights using light emitting diodes may be considered that are in accordance with:

- IMO Res. MSC.253(83), *Performance Standards for Navigation Lights, Navigation Light Controllers and associated Equipment*, and
- EN 14744, *Inland navigation vessels and sea-going vessels – Navigation light*, or a relevant National, International or Naval Standard.

Where alternative measures are proposed that require verification by personnel of the luminous intensity of navigation lights using light emitting diodes, details of the periodic inspection implementation and acceptance by the Naval Administration are to be submitted for consideration.

4.5.7 Navigation light power supply units installed to convert, control and/or monitor the distribution board power supply required by *Vol 2, Pt 9, Ch 7, 4.7 Valve control and indication systems 4.7.1* above for connection to the light source(s) (e.g. for LED type navigation lights) are, in the event of a short-circuit on the unit output, to disconnect or limit the supply to prevent further damage and activate an alarm.

4.5.8 Navigation light power supply units are to be self-monitoring, detecting failures of the unit itself and activating an alarm. These are to include:

- detection of system lock-ups (program hangs);
- means to detect failure of navigation light switching command input circuits or links; and
- means to detect failure of the navigation light monitoring arrangements required to provide the alarms required by *Vol 2, Pt 9, Ch 7, 4.7 Valve control and indication systems 4.7.4* and *Vol 2, Pt 9, Ch 7, 4.7 Valve control and indication systems 4.7.5*, as applicable.

4.5.9 The navigation light power supply failure alarms required by *Vol 2, Pt 9, Ch 7, 4.7 Valve control and indication systems 4.7.1* are not to be displayed as a group alarm. Other navigation light alarms may be grouped for each navigation light where means are provided for personnel to determine the cause of the alarm. Activation of more than one of the navigation light alarms as a result of a single failure is to be prevented.

4.5.10 Specified requirements including the use of battery power navigation lights are to be complied with and may be accepted as an alternative to the above.

4.6 Escape route or low location lighting (LLL)

4.6.1 The escape route or low location lighting (LLL) required by the Naval Administration specified standard, where satisfied by electric illumination, is to comply with the requirements of this sub-Section.

4.6.2 The LLL system is to be provided with an emergency source of electrical power as required by *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power* and also be connected to the main source of electrical power, with automatic changeover facilities located adjacent to the control panel, *see also Vol 2, Pt 9, Ch 1, 2.5 Operation under fire conditions*.

4.6.3 The power supply arrangements to the LLL are to be arranged so that a single fault or a fire in any one fire zone or deck does not result in loss of the lighting in any other zone or deck. This requirement may be satisfied by the power supply circuit configuration, use of fire-resistant cables complying with *Vol 2, Pt 9, Ch 3, 8.5 Construction 8.5.3*, and/or the provision of suitably located power supply units having integral batteries adequately rated to supply the connected LLL for a minimum period of 60 minutes.

4.6.4 The performance and installation of lights and lighting assemblies are to comply with ISO standard 15370: *Ships and marine technology – Low location lighting on passenger ships*.

■ Scope

The requirements of this Chapter are applicable to the design and construction philosophy of machinery control, alert and safety systems as well as ship safety systems that are essential to the safety of a naval vessel.

This Chapter details the requirements for hard wired, solid state and programmable electronic systems within the boundary for provision of Mobility and/or Ship Type systems.

Application of this Chapter will facilitate the verification of the performance requirements of *ANEP-77 NATO Naval Ship Code*, Chapter IV, Regulations 13, 14 and 15.

■ *Section 1* Functional requirements

1.1 Functional requirements

1.1.1 Systems for propulsion and manoeuvring, and electrical power generation and safety of the ship shall be provided with effective means of control and alert to ensure fault identification and safe operation under all ship operational conditions.

1.1.2 Alert systems shall inform Operators as soon as reasonably practicable of deviations from normal operation of Mobility and/or Ship Type systems during all ship operations.

1.1.3 Safety systems shall ensure that any serious faults of machinery or system which present an immediate danger shall initiate corrective action, where appropriate, to remove the risk of danger.

■ *Section 2* Performance requirements

2.1 Performance requirements

2.1.1 The design, construction and operation of control, alert and safety systems shall employ human-centred activities.

2.1.2 Mobility systems for propulsion and manoeuvring, electrical power generation, and safety of the ship shall be provided with a continuous electrical supply. An audible and visual alert shall be initiated in the event of the failure of any of the power supplies.

2.1.3 The control system must operate Mobility and/or Ship Type systems in a safe, controlled and stable manner throughout the machinery's/systems' defined operational limits and shall recover automatically in a safe manner after a loss of power supply.

2.1.4 It shall be possible to control machinery/systems from only one location at a time, with clear indication showing the location of the control. Transfer between control stations without altering the control set points shall be provided. Transfer of control location will be indicated with visual and audible indication.

2.1.5 Appropriate indication and feedback shall be provided at each control station to confirm that the system has responded to the Operator's demands. The status of automatic control systems shall be indicated.

2.1.6 Means are to be available to disable the automatic or remote control operation of Mobility and/or Ship Type systems to allow inspection and maintenance tasks to be performed safely on the machinery and systems.

2.1.7 Indications of impending slowdown/shutdown of Mobility and/or Ship Type systems shall be provided at applicable locations with provision to take alternative actions if approved.

2.1.8 Automated control systems which utilise stored energy to start Mobility and/or Ship Type machinery shall be configured not to exhaust the stored energy completely and to provide an alert when the stored energy is below a critical limit.

2.1.9 The monitoring system for system parameters is to have integrity appropriate for its intended purpose.

2.1.10 Where it is proposed to operate the Mobility or Ship Type machinery in an unattended space, no matter what period, sufficient controls, alarms and safeguards are to be provided to enable safe and effective operation of the equipment. A dedicated control position shall be provided.

2.1.11 Failure of a control system is not to result in the loss of ability to provide either Mobility or Ship Type systems by alternative means.

2.1.12 Control, Alert and Safety systems shall be designed to fail to the least hazardous condition. This condition shall be determined for the complete installation.

2.1.13 Operators shall have an independent, high integrity method to disconnect all energy sources that shall put machinery for Ship Type safety functions into a known safe state.

2.1.14 An alert system with appropriate controls and displays shall be located at key locations.

2.1.15 Where parameters of the alert system can be adjusted, the integrity of the system shall be maintained.

2.1.16 The status of an alert shall be clearly visible and a means to accept it from all appropriate locations. Visual indication of the alarm shall remain until the fault is cleared.

2.1.17 Design of machinery safety systems shall be such that equipment must be reset manually before being restarted.

2.1.18 Where the function of a safety system might lead to a greater hazard than the loss of the equipment, an override should be provided.

2.1.19 The status of standby machinery and systems shall be indicated at appropriate control stations as agreed with the Naval Administration.

2.1.20 Systems shall be readily usable under all intended operating conditions and shall support effective and efficient operation. Adequate safeguards against incorrect operation shall be provided.

2.1.21 The systems' repeatability and accuracy shall be adequate for the proposed use and shall be maintained at their specified value during their expected lifetime and normal use.

2.1.22 System design shall take account of any constraints or limitations imposed due to equipment or machinery.

■ *Section 3*
Verification requirements

3.1 General

3.1.1 Compliance with the requirements in *Vol 2, Pt 9, Ch 7, 4 Essential features for control, alarm and safety systems* inclusive is deemed to satisfy the functional requirements and performance requirements above.

3.1.2 Where a designer offers a novel solution, an engineering safety and justification report is to be submitted. The engineering safety and justification report is to demonstrate how the proposed solution will satisfy the functional requirements and performance requirements in *Vol 2, Pt 9, Ch 7, 1 Functional requirements* and *Vol 2, Pt 9, Ch 7, 2 Performance requirements*.

3.1.3 The Naval Administration may impose requirements additional to those in this Chapter.

Section 4
Essential features for control, alarm and safety systems

4.1 General

4.1.1 This Chapter applies to systems providing control, alarm or safety functions for the following:

- Mobility category engineering systems.
- Ship Type category engineering systems.

4.1.2 The design, construction and installation of control alarm and safety systems and control stations shall incorporate the ergonomics requirements of *Vol 2, Pt 10 Human Factors*.

4.2 Control stations for machinery

4.2.1 Each machinery control station is to be provided with sufficient indication to ensure effective control of machinery and engineering systems and ready identification of faults. Indication should be provided, at least, for those parameters required to be monitored by relevant parts of these Rules.

4.2.2 At the main control station (if provided) or close to the subsidiary stations (if fitted) means of communication with the bridge area, the accommodation for engineering personnel and, if necessary, the machinery spaces are to be provided.

4.2.3 Provision is to be made at the main control station, or subsidiary control stations as appropriate, for the operation of an engineers' alarm which is to be clearly audible in the engineers' accommodation.

4.2.4 Provision is to be made at the main control station and any other subsidiary control station from which the main propulsion and auxiliary machinery or associated equipment may be controlled to indicate which station is in control.

4.2.5 Control of machinery, and associated equipment is to be possible only from one station at a time.

4.2.6 Changeover between control stations is to be arranged so that it may only be effected with the acceptance of the station taking control. The system is to be provided with interlocks or other suitable means to ensure effective transfer of control.

4.3 Alarm systems, general requirements

4.3.1 Where an alarm system is to be provided alerting relevant personnel to faults, abnormal situations and the other conditions requiring attention in machinery and engineering systems required by this Chapter or other Sections of the Rules, alarm information is to be displayed at the main control station or, alternatively, at subsidiary control stations. In the latter case, a master alarm display is to be provided at the main control station showing which of the subsidiary control stations is indicating a fault.

4.3.2 Machinery, safety and control system faults are to be indicated at the relevant control stations to advise duty personnel of a fault condition. The presence of unrectified faults is to be clearly indicated at all times.

4.3.3 Alerts associated with machinery and equipment required to satisfy this sub-Section are to be categorised according to the urgency and type of response required by the crew, as described in the IMO *Code on Alerts and Indicators, 2009*. The assignment of category to each alert is to be evaluated on the basis not only of the machinery or equipment being monitored, but also the complete installation. Categories not included in an alarm system may be omitted from the system design. Details of alternative alert management proposals supported with evidence of service experience may be submitted for consideration by LR. The alternative alert management is to be clearly specified.

4.3.4 Where the facility to provide messages in association with alerts exists, messages accompanying alerts are to describe the condition and indicate the intended response required by the crew.

4.3.5 Where the facility to provide messages in association with alerts exists, messages of different categories are to be clearly distinguishable from each other.

4.3.6 Alarms associated with machinery, safety and control system faults are to be clearly distinguishable from other alarms (e.g. fire, general alarm).

4.3.7 Where alarms are displayed as group alarms, provision is to be made to identify individual alarms at the main control station (if fitted) or alternatively at subsidiary control stations.

4.3.8 All alarms are to be both audible and visual. If arrangements are made to silence audible signals they are not to extinguish visual indications.

4.3.9 Acknowledgement of visual alarms is to be clearly indicated.

4.3.10 Acknowledgement of alarms at positions outside a machinery space is not to silence the audible signal or extinguish the visual indication in that machinery space.

4.3.11 If an alarm has been acknowledged and a second fault occurs prior to the first being rectified, audible signals and visual indications are again to operate. Where alarms are displayed at a local panel adjacent to the machinery and with arrangements to provide a group or common fault alarm in the control room then the occurrence of a second fault prior to the first alarm being rectified need only be displayed at the local panel, however the group alarm is to be re-initated. Unacknowledged alarms on monitors are to be distinguished by either flashing text or a flashing marker adjacent to the text. A change of colour will not in itself be sufficient to distinguish between acknowledged and unacknowledged alarms.

4.3.12 For the detection of transient faults which are subsequently self-correcting, alarms are required to lock in until accepted.

4.3.13 The alarm system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply. Where an alarm system could be adversely affected by an interruption in power supply, changeover to the standby power supply is to be achieved without a break.

4.3.14 Failure of any power supply to the alarm system is to operate an audible and visual alarm.

4.3.15 The alarm system should be designed with self-monitoring properties. Insofar as practicable, any fault in the alarm system should cause it to fail to the alarm condition.

4.3.16 The alarm system is to be capable of being tested during normal machinery operation, *see Vol 2, Pt 9, Ch 11, 1.2 Trials 1.2.2*.

4.3.17 The alarm system is to be designed as far as practicable to function independently of control and safety systems such that a failure or malfunction in these systems will not prevent the alarm system from operating.

4.3.18 Disconnection or manual overriding of any part of the alarm system is to be clearly indicated.

4.3.19 When alarm systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

4.3.20 Where monitors are provided at the station in control and, if fitted, in the duty engineer's accommodation, they are to provide immediate display of new alarm information regardless of the information display page currently selected. This may be achieved by provision of a dedicated alarm monitor, a dedicated area of screen for alarms or other suitable means.

4.3.21 Where practicable, alarms displayed on monitors are to be displayed in the order in which they occur. Alarms requiring manual shutdown or slowdown action are to be given visual prominence.

4.3.22 Means are to be provided to test alarm and other indicator lamps.

4.3.23 Where a first stage alarm together with a second stage alarm and automatic shutdown of machinery are required in the relevant Table of this Section, the sensors and circuits utilised for the second stage alarm and automatic shutdown are to be independent of those required by the first stage alarm.

4.4 Safety systems, general requirements

4.4.1 Safety systems are to operate automatically in case of serious faults endangering the machinery, so that:

(a) normal operating conditions are restored, e.g. by the starting of standby machinery; or
(b) the operation of the machinery is temporarily adjusted to the prevailing conditions, e.g. by reducing the output of the machinery; or
(c) the machinery is protected from critical conditions by shutting off the fuel or power supplies thereby stopping the machinery.

4.4.2 The safety system is to be designed as far as practicable to operate independently of the control and alarm systems, such that a failure or malfunction in the control and alarm systems will not prevent the safety system from operating.

4.4.3 Safety systems for different items of the machinery plant are to be arranged so that failure of the safety system of one part of the plant will not interfere with the operation of the safety system in another part of the plant.

4.4.4 The safety system is to be designed to 'fail safe'. The characteristics of the 'fail safe' operation are to be evaluated on the basis not only of the safety system and its associated machinery, but also the complete installation. Failure of a safety system is to initiate an audible and visual alarm.

4.4.5 When a safety system is activated, an audible and visual alarm is to be provided to indicate the cause of the safety action.

4.4.6 The safety system is to be manually reset before the relevant machinery can be restarted.

4.4.7 Where arrangements are provided for overriding a safety system, they are to be such that inadvertent operation is prevented. Visual indication is to be given at the relevant control station(s) when a safety override is operated. The consequences of overriding a safety system are to be established and documented.

4.4.8 The safety system is to be arranged with automatic changeover to a standby power supply in the event of a failure of the normal power supply.

4.4.9 Failure of any power supply to a safety system is to operate an audible and visual alarm.

4.4.10 When safety systems are provided with means to adjust their set point, the arrangements are to be such that the final settings can be readily identified.

4.4.11 As far as practicable, the safety system required by *Vol 2, Pt 9, Ch 7, 4.4 Safety systems, general requirements 4.4.1* is to be arranged to effect a rapid reduction in speed or power.

4.5 Control systems, general requirements

4.5.1 The control system is to be designed such that normal operation of the controls cannot induce detrimental mechanical or thermal overloads in the machinery.

4.5.2 Control systems for machinery operations are to be stable throughout their operating range.

4.5.3 Failure of any power supply to a control system is to operate an audible and visual alarm.

4.5.4 Control systems should be designed to ‘fail safe’. The characteristics of the ‘fail safe’ operation are to be evaluated on the basis not only of the control system and its associated machinery, but also the complete installation.

4.5.5 Remote or automatic controls are to be provided with suitable instrumentation (e.g. alarms and indications) at the relevant control stations to ensure effective control by duty personnel and to indicate that the system is functioning correctly.

4.5.6 When control systems are provided with means to adjust their sensitivity or set point, the arrangements are to be such that the final settings can be readily identified.

4.5.7 Failure of a control system is not to result in the loss of ability to provide Mobility and/or Ship Type systems by alternative means. This may be achieved by manual control or redundancy within the control system or redundancy in machinery and equipment, *see also Vol 2, Pt 9, Ch 8, 5.5 Additional requirements for integrated systems 5.5.2*. Instrumentation is to be provided at local manual control stations to ensure effective operation of the machinery by duty personnel.

4.6 Bridge control for main propulsion machinery

4.6.1 Means are to be provided to ensure satisfactory control of propulsion from the bridge in both the ahead and astern directions.

4.6.2 The following indications are to be provided on the bridge:

(a) Propeller speed.
(b) Direction of rotation of propeller for a fixed pitch propeller or pitch position for a controllable pitch propeller. *See also Vol 2, Pt 4, Ch 1, 10.2 Automatic and remote controls 10.2.3*.
(c) Direction and an indication representative of the magnitude of the thrust.
(d) Clutch position where applicable.
(e) Shaft brake position where applicable.

4.6.3 The propeller speed, direction of rotation and, if applicable, the propeller pitch are to be controlled from the bridge under all normal sea going and manoeuvring conditions.

4.6.4 Remote control of the propulsion machinery is to be from only one control station at any one time, *see also Vol 2, Pt 9, Ch 7, 4.2 Control stations for machinery 4.2.5*. Main propulsion control units on the navigating bridge may be interconnected. Means are to be provided at the control station to ensure smooth transfer of control between the bridge and other control stations.

4.6.5 Means of control, independent of the bridge control system, are to be provided on the bridge to enable the propulsion machinery to be stopped in an emergency.

4.6.6 Audible and visual alarms are to operate on the bridge and in the alarm system required by *Vol 2, Pt 9, Ch 7, 4.2 Control stations for machinery* if any power supply to the bridge control system fails. Where practicable, the preset speed and direction of thrust are to be maintained until corrective action is taken.

4.6.7 At least two means of communication are to be provided between the bridge and the main control station in the machinery space. One of these means may be the bridge control system; the other is to be independent of the main electrical power supply. *See also Vol 2, Pt 9, Ch 7, 4.2 Control stations for machinery 4.2.2* and *Vol 2, Pt 1, Ch 3, 5.10 Communications*.

4.6.8 Automation systems are to be designed in a manner such that a threshold warning of impending or imminent slowdown or shutdown of the propulsion system is given to the officer in charge of the navigational watch in time to assess navigational circumstances in an emergency. In particular, the systems are to control, monitor, report, alert and take safety action to slow down or stop propulsion while providing the officer in charge of the navigational watch an opportunity to manually intervene, except for those cases where manual intervention will result in total failure of the engine and/or propulsion equipment within a short time, for example in the case of overspeed.

4.7 Valve control and indication systems

4.7.1 Systems providing remote control and indication functions for valves in Mobility and Ship Type category systems are to ensure effective operation, with due regard to any specified requirements for operation under damage conditions. The requirements of *Vol 2, Pt 9, Ch 7, 4.7 Valve control and indication systems 4.7.2*are to be satisfied.

4.7.2 Failure of control system power or actuator power is not to permit a valve to move to an unsafe condition.

4.7.3 Positive indication is to be provided at the remote control station for the service to show the actual valve position or alternatively that the valve is fully open or closed.

4.7.4 Equipment located in places which may be flooded is to be capable of operating when submerged.

4.7.5 A secondary means of operating the valves, which may be by local manual control, is to be provided.

4.7.6 For requirements applicable to closing appliances on scuppers and sanitary discharges, *see Vol 1, Pt 3, Ch 4, 8 Scuppers and sanitary discharges*

■ Scope

The requirements of this Chapter are applicable to the design and construction philosophy of Programmable Electronic Systems used for machinery control, alert and safety systems as well as ship safety systems that are essential to the safety of a naval vessel.

This Chapter details the requirements for programmable electronic systems within the boundary for provision of both Mobility and Ship Type systems.

Application of this Chapter will facilitate the verification of the performance requirements of *ANEP-77 NATO Naval Ship Code*, Chapter IV, Regulation 15.

■ *Section 1* Functional requirements

1.1 Functional requirements

1.1.1 Additional hazards shall not be introduced by the application of programmable electronic systems.

1.1.2 The integration of systems or sub-systems shall ensure the required functionality of the platform under normal and foreseeable abnormal conditions and shall not introduce additional hazards.

■ *Section 2* Performance requirements

2.1 Performance requirements

2.1.1 The design, construction and operation of programmable systems shall employ human-centred activities.

2.1.2 The required level of safety shall be realised by appropriate activities throughout the equipment lifecycle.

2.1.3 The Programmable Electronic Systems shall be arranged such that the configuration is protected against unauthorised or unintended change.

2.1.4 Where applicable, the synchronisation of date and time stamping between separate equipment should be considered.

2.1.5 There shall be no degradation of the sub-system functionality when integrated into a larger system.

2.1.6 Programmable electronic systems shall maintain specified levels of performance in operation, and where necessary, under fault conditions.

2.1.7 Systems shall be readily usable under all intended operating conditions and shall support effective and efficient operation. Adequate safeguards against incorrect operation shall be provided.

2.1.8 The systems' repeatability and accuracy shall be adequate for the proposed use and shall be maintained at their specified value during their expected lifetime and normal use.

2.1.9 Program and data held in the system shall be protected from corruption by loss of power.

2.1.10 The Programmable Electronic Systems configuration shall be identified and controlled throughout the lifecycle.

2.1.11 System design shall take account of any constraints or limitations imposed due to equipment or machinery.

2.1.12 Failure of one part of the integrated system shall not affect the functionality of other parts except for those functions directly dependent on the defective part.

■ *Section 3* Verification requirements

3.1 General

3.1.1 Compliance with the requirements in *Vol 2, Pt 9, Ch 8, 4 General requirements* inclusive is deemed to satisfy the functional requirements and performance requirements above.

3.1.2 Where a designer offers a novel solution, an engineering safety and justification report is to be submitted. The engineering safety and justification report is to demonstrate how the proposed solution will satisfy the functional requirements and performance requirements in *Vol 2, Pt 9, Ch 8, 1 Functional requirements*.

3.1.3 The Naval Administration may impose requirements additional to those in this Chapter.

■ *Section 4* General requirements

4.1 General

4.1.1 The design, construction and installation of programmable electronic systems shall incorporate the ergonomics requirements of *Vol 2, Pt 10 Human Factors*.

■ *Section 5* Programmable electronic systems (PES)

5.1 General requirements

5.1.1 The requirements of this Section are to be complied with where control, alarm or safety systems incorporate programmable electronic equipment. Mobility systems, Ship Type systems and safety critical systems incorporating shared data communication links and systems which are integrated are to comply with the additional requirements of *Vol 2, Pt 9, Ch 8, 5.2 Data communication links*, *Vol 2, Pt 9, Ch 8, 5.3 Additional requirements for wireless data communication links* and *Vol 2, Pt 9, Ch 8, 5.4 Additional requirements for Mobility category and safety critical systems* as applicable. .

5.1.2 Systems complying with ISO 17894, *Ships and marine technology – Computer applications – General principles for the development and use of programmable electronic systems in marine applications,* may be accepted as meeting the requirements of this Section in which case evidence of compliance is to be submitted for consideration.

5.1.3 Where programmable electronic systems share resources, any components that can affect the ability to effectively provide required control, alarm or safety functions are to fulfil the requirements of *Vol 2, Pt 9, Ch 8, 5.1 General requirements* related to providing those required functions.

5.1.4 Programmable electronic equipment is to revert to a defined safe state on initial start up or re-start in the event of failure.

5.1.5 In the event of failure of any programmable electronic equipment, the system, and any other system to which it is connected, is to fail to a defined safe state or maintain safe operation, as applicable.

5.1.6 Programmable electronic equipment is to be certified by a recognised authority as suitable for the environmental conditions in which it is intended to operate, *see also Vol 2, Pt 9, Ch 8, 5.4 Additional requirements for Mobility category and safety critical systems 5.4.3*.

5.1.7 Emergency stop functions are to be hard-wired and independent of any programmable electronic equipment. Alternatively, the system providing emergency stop functions is to comply with the requirements of *Vol 2, Pt 9, Ch 8, 5.4 Additional requirements for Mobility category and safety critical systems 5.4.2* and/or *Vol 2, Pt 9, Ch 8, 5.4 Additional requirements for Mobility category and safety critical systems 5.4.8*.

5.1.8 Programmable electronic equipment is to be provided with self-monitoring capabilities such that hardware and functional failures will initiate an audible and visual alarm in accordance with the requirements of *Vol 2, Pt 9, Ch 7, 4.3 Alarm systems, general requirements* and, where applicable, *Vol 2, Pt 9, Ch 1, 4.2 Alarm systems for machinery*. Hardware failure indications are to enable faults to be identifiable at least down to the level of the lowest replaceable unit and the self-monitoring capabilities are to ensure that diagnostic information is readily available.

5.1.9 Means are to be provided to recover or replace data required for safe and effective system operation lost as a result of component failure. The submission required by *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.8* is to address reinstatement of system operation following data loss.

5.1.10 System configuration, programs and data are to be protected against loss or corruption in the event of failure of any power supply. For Mobility category and safety critical systems, *see Vol 2, Pt 9, Ch 8, 5.4 Additional requirements for Mobility category and safety critical systems 5.4.6*.

5.1.11 Where it is necessary to store data required for system operation in volatile memory, a back-up power supply is to be provided that prevents data loss in the event of loss of the normal power supply. The submission required by *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.21* is to include details of any routine maintenance necessary and the measures necessary to restore system operation in the event of data loss as a result of power supply failure.

5.1.12 Back-up power supplies required by *Vol 2, Pt 9, Ch 8, 5.1 General requirements 5.1.11* are to be rated to supply the connected load for a defined period of time that allows sufficient time for the re-instatement of supply in the event of loss of the normal power supply as a result of failure of a main source of electrical power. This period is in any case to be not less than 30 minutes.

5.1.13 Where regular battery replacement is required to maintain the availability of volatile memory back-up power supply required by *Vol 2, Pt 9, Ch 8, 5.1 General requirements 5.1.11*, these are to be included in the schedule of batteries required by *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.17* and *Vol 2, Pt 9, Ch 2, 7.7 Recording of batteries for emergency and essential services*, irrespective of battery type and size. Applicable entries in this schedule are to note that these batteries are not for safety critical systems, Mobility systems, Ship Type systems, or emergency services.

5.1.14 Access to system configuration, programs and data is to be restricted by physical and/or logical means providing effective security against unauthorised alteration.

5.1.15 Where date and time information is required by the equipment, this is to be provided by means of a battery backed clock with restricted access for alteration. Date and time information is to be fully represented and utilised.

5.1.16 Displays and controls are to be protected against liquid ingress due to spillage or spraying.

5.1.17 Display units are to comply with the requirements of an acceptable National or International Standard, e.g. IEC 60950 in respect of emission of ionising radiation.

5.1.18 Where systems detect fault conditions, any affected mimic diagrams are to ensure that the status of unreliable and incorrect data is clearly identified.

5.1.19 Multi-function displays and controls are to be duplicated and interchangeable where used for the control or monitoring of more than one system, machinery item or item of equipment. At least one unit at the main control station is to be supplied from an independent uninterruptible power system (UPS).

5.1.20 The number of multi-function display and control units provided at the main control station and their power supply arrangements are to be sufficient to ensure continuing safe operation from a multi-function display and control unit in the event of failure of any unit or any power supply.

5.1.21 Software lifecycle activities, e.g. design, development, supply and maintenance, are to be carried out in accordance with an acceptable quality management system. Software quality plans are to be submitted. These are to demonstrate that the provisions of ISO/IEC 90003:2014 *Software engineering – Guidelines for the application of ISO 9001:2008 to computer software* or an acceptable International, National or naval standard, are incorporated. The plans are to define responsibilities for the lifecycle activities, including verification, validation, module testing and integration with other components or systems.

5.2 Data communication links

5.2.1 Where control, alarm or safety systems use shared data communication links to transfer data, the requirements of *Vol 2, Pt 9, Ch 8, 5.2 Data communication links 5.2.2* are to be complied with. The requirements apply to local area networks, fieldbuses and other types of data communication link which make use of a shared medium to transfer control, alarm or safety related data between distributed programmable electronic equipment or systems.

5.2.2 Data communication is to be automatically restored within 45 seconds in the event of a single component failure. Upon restoration, priority is to be given to updating safety critical data and control, alarm and safety related data for Mobility and/or Ship Type systems. Components comprise all items required to facilitate data communication, including cables, switches, repeaters, software components and power supplies.

5.2.3 Loss of a data communication link is not to result in the loss of ability to operate any Mobility or Ship Type system by alternative means, *see also Vol 2, Pt 9, Ch 8, 5.4 Additional requirements for Mobility category and safety critical systems 5.4.2*.

5.2.4 The properties of the data communication link, (e.g. bandwidth, access control method, etc.), are to ensure that all connected systems will operate in a safe, stable and repeatable manner under all operating conditions. The latency of control, alarm and safety related data is not to exceed two seconds.

5.2.5 Protocols are to ensure the integrity of control, alarm and safety related data, and provide timely recovery of corrupted or invalid data.

5.2.6 Means are to be provided to monitor performance and identify hardware and functional failures. An audible and visual alarm is to operate in accordance with the requirements of *Vol 2, Pt 9, Ch 7, 4.3 Alarm systems, general requirements* and, where applicable, *Vol 2, Pt 9, Ch 1, 4.2 Alarm systems for machinery* in the event of a failure of an active or standby component.

5.2.7 System self-monitoring capabilities are to be arranged to initiate transition to a defined safe state for the complete installation in the event of data communication failure, *see also Vol 2, Pt 9, Ch 7, 4.5 Control systems, general requirements 4.5.4*.

5.2.8 Means are to be provided to prevent unintended connection or disconnection of any equipment where this may affect the performance of any other systems in operation.

5.2.9 Data cables are to comply with the applicable requirements of *Vol 2, Pt 9, Ch 3, 8 Electric cables, optical fibre cables and busbar trunking systems (busways)* . Other media will be subject to special consideration.

5.2.10 The installation is to provide adequate protection against mechanical damage and electromagnetic interference.

5.2.11 Components are to be located with appropriate segregation such that the risk of mechanical damage or electromagnetic interference resulting in the loss of both active and standby components is minimised. Duplicated data communication links are to be routed to give as much physical separation as is practical.

5.3 Additional requirements for wireless data communication links

5.3.1 The requirements of this sub-Section are in addition to *Vol 2, Pt 9, Ch 8, 5.2 Data communication links* and apply to systems incorporating wireless data communication links.

5.3.2 Wireless data communication links are not to be used for safety critical systems, Mobility systems or Ship Type systems that are required for the propulsion or safety of the ship, except as permitted by *Vol 2, Pt 9, Ch 8, 5.3 Additional requirements for wireless data communication links 5.3.3*.

5.3.3 For services which need not be in operation continuously, wireless data communication links may be considered where an alternative means of operation that can be brought into action within an acceptable period of time is provided.

5.3.4 Wireless data communication is to employ recognised international wireless communication system protocols that incorporate the following:

(a) Message integrity: fault prevention, detection, diagnosis, and correction ensuring the received message is not corrupted or altered when compared to the transmitted message.
(b) Configuration and device authentication: is only to permit connection of devices that are included in the system design.
(c) Message encryption: protection of the confidentiality and/or criticality of the data content.

(d) Security management: protection of network assets, prevention of unauthorised access to network assets.

5.3.5 The wireless system is to comply with the radio frequency and power level requirements of the International Telecommunications Union and any requirements of the National Administration with which the ship is registered.

5.3.6 Compliance with different port state and local regulations pertaining to the use of radio-frequency transmission that would prohibit the operation of a wireless data communication link, due to frequency and power level restrictions, is not addressed by these requirements and is the responsibility of the Owner.

5.4 Additional requirements for Mobility category and safety critical systems

5.4.1 The requirements of *Vol 2, Pt 9, Ch 8, 5.4 Additional requirements for Mobility category and safety critical systems 5.4.2* are to be complied with where control, alarm or safety functions for Mobility category, or safety critical systems, incorporate programmable electronic equipment.

(a) Safety critical systems are those which provide functions intended to protect persons from physical hazards caused by engineering system failures, e.g. fire, explosion, etc. or to prevent mechanical damage which may result in the loss of a Mobility category system, e.g. main engine low lubricating oil pressure shutdown.
(b) Functions provided by Ship Type or Ancillary category systems may also be considered to be safety critical, e.g. domestic boiler low water level shutdown.

5.4.2 Alternative means of safe and effective control are to be provided for Mobility category systems. Back up control systems are to be of diverse design, and are to operate independently of the main control system. Where design diversity of control system software is not practicable, the software is to satisfy the requirements of LR's *Software Conformity Assessment System – Assessment Module GEN1 (1994)*.

5.4.3 Items of programmable electronic equipment used to implement control, alarm or safety functions are to be Type Approved in accordance with LR's Type Approval System, *Test Specification Number 1 (2002)*. Type approval to an alternative and relevant National or International Standard may be submitted for consideration.

5.4.4 The system is to be configured such that control, alarm and safety function groups are independent. A failure of the system is not to result in the loss of more than one of these function groups. Proposals for alternative arrangements providing an equivalent level of safety will be subject to special consideration.

5.4.5 For Mobility and/or Ship Type, the system is to be arranged to operate automatically from an alternative power supply in the event of a failure of the normal supply.

5.4.6 Volatile memory is not to be used to store data required to:

- provide a Mobility category system or safety critical function; or
- ensure safety or prevent damage, including during startup or re-start.

Alternative proposals that demonstrate an equivalent level of system integrity will be achieved may be submitted for consideration.

5.4.7 Failure of any power supply is to initiate an audible and visual alarm in accordance with the requirements of *Vol 2, Pt 9, Ch 7, 4.3 Alarm systems, general requirements* and, where applicable, *Vol 2, Pt 9, Ch 1, 4.2 Alarm systems for machinery*.

5.4.8 Where it is intended that the programmable electronic system implements an emergency stop functions or safety critical functions, the software is to satisfy the requirements of LR's *Software Conformity Assessment System – Assessment Module GEN1 (1994)*. Alternative proposals providing an equivalent level of system integrity will be subject to special consideration, e.g. fully independent hard wired back-up system, redundancy with design diversity, etc.

5.4.9 Control, alarm and safety related information is to be displayed in a clear, unambiguous and timely manner, and, where applicable, is to be given visual prominence over other information on the display.

5.4.10 Means of access to safety critical functions are to be dedicated to the intended function and readily distinguishable.

5.5 Additional requirements for integrated systems

5.5.1 The requirements of *Vol 2, Pt 9, Ch 8, 5.5 Additional requirements for integrated systems 5.5.2* apply to integrated systems such as those providing a grouping of fire safety or crew and embarked personnel emergency safety functions (*see Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems Vol 2, Pt 9, Ch 8 Programmable Electronic Systems*, *Vol 2, Pt 9, Ch 9 Fire Safety and Ship Safety Systems* and *Vol 2, Pt 9, Ch 10 Internal Communication*), power management systems and integrated control, alarm and monitoring systems for machinery, and include the interconnection of systems capable of independent operation to provide co-ordinated functions or common user interfaces.

5.5.2 System integration is to be managed by a single designated party, and is to be carried out in accordance with a defined procedure identifying the roles, responsibilities and requirements for all parties involved. This procedure is to be submitted for consideration where the integration involves control functions for Mobility category systems or safety critical functions.

5.5.3 The system requirements specification, *see Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.21*, is to identify the allocation of functions between modules of the integrated system, and any common data communication protocols or interface standards required to support these functions.

5.5.4 Reversionary modes of operation are to be provided to ensure safe and graceful degradation in the event of one or more failures. In general, the integrated system is to be arranged such that the failure of one part will not affect the functionality of other parts, except those that require data from the failed part.

5.5.5 Where the integration involves control functions for Mobility systems, Ship Type systems, or safety functions, including fire safety or crew and embarked personnel or emergency safety functions, the Risk Assessment (RA) required by *Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.7* is to additionally to demonstrate that the integrated system will 'fail-safe', *see Vol 2, Pt 9, Ch 7, 4.4 Safety systems, general requirements 4.4.3* and *Vol 2, Pt 9, Ch 7, 4.5 Control systems, general requirements 4.5.4*, and that Mobility and/or Ship Type systems in operation will not be lost or degraded beyond acceptable performance criteria where specified by these Rules.

5.5.6 The quantity and quality of information presented to the Operator are to be managed to assist situational awareness in all operating conditions. Excessive or ambiguous information that may adversely affect the Operator's ability to reason or act correctly is to be avoided, but information needed for corrective or emergency actions is not to be suppressed or obscured in satisfying this requirement.

5.5.7 Where information is required by the Rules or by the System Design Description requirements to be continuously displayed, the system configuration is to be such that the information may be viewed without manual intervention, e.g. the selection of a particular screen page or mode of operation. *See also Vol 2, Pt 9, Ch 8, 5.1 General requirements 5.1.21*.

5.5.8 Where applicable, date and time stamping between separate equipment shall be synchronised.

■ Scope

The requirements of this Chapter are applicable to the design and construction philosophy of the electrotechnical Classification aspects of Fire Safety and Ship Safety ships including Fire detection and alarms system, local application fire-fighting systems, watertight doors and power supply arrangements to other essential fire safety systems.

This Chapter details the requirements for sub-systems and equipment within the boundary of Fire Safety and Ship Safety ships in machinery and accommodation spaces.

Application of this Chapter will facilitate the verification of the performance requirements of *ANEP-77, NATO Naval Ship Code*, Chapter VI, Regulation 7.

■ *Section 1*
Functional requirements

1.1 Functional requirements

1.1.1 A fire in the space of origin shall be detected and an alarm shall be provided for safe escape and fire-fighting activity.

1.1.2 Power to fire safety and ship safety systems shall be maintained in all reasonably foreseeable abnormal conditions.

1.1.3 A means of isolating ventilation and oil or fuel supplies to a space containing a fire shall be provided.

■ *Section 2*
Performance requirements

2.1 Performance requirements

2.1.1 An effective means of detecting and locating fires and alerting the navigation bridge, continuously manned control station and fire teams is to be provided in accordance with the IMO *FSS Code - Fire Safety Systems – Resolution MSC.98(73)*.

2.1.2 Fixed fire detection and fire alarm system installations shall be suitable for the nature of the space, fire growth potential and potential generation of smoke and gases.

2.1.3 Manually operated call points shall be placed effectively to ensure a readily accessible means of notification.

2.1.4 The fire alarm is to sound the ship's general alarm if not responded to within a defined timescale.

2.1.5 Fixed fire detection and fire alarm system installations are to be demonstrated in accordance with a recognised Standard and shall be tested periodically in accordance with a recognised procedure.

2.1.6 Automatic activation of fire-fighting systems should have due regard for the function of the space and equipment protected.

2.1.7 Cable routes which supply power to fire safety and ship safety systems are to avoid high risk areas.

2.1.8 The activation of detection or extinction systems shall not result in the loss of Mobility and/or Ship Type systems.

2.1.9 In the event of a fire, all equipment which could continue to provide a source of fuel or oxygen shall have the ability to be stopped remotely from outside the space.

2.1.10 Controls to fire safety systems shall be located outside of the space in which they serve.

2.1.11 All fire safety and ship safety systems shall be designed on the fail-safe principle.

2.1.12 The enclosures of electrical and control components necessarily situated below the bulkhead deck are to provide suitable protection against the ingress of water.

2.1.13 System design of all watertight and semi-watertight door systems is to ensure that a failure will not result in incorrect operation that will present a danger to the ship or personnel.

■ *Section 3* Verification requirements

3.1 General

3.1.1 Compliance with the requirements in *Vol 2, Pt 9, Ch 9, 4 Fire detection and fire alarm systems* inclusive is deemed to satisfy the functional requirements and performance requirements above.

3.1.2 Where a designer offers a novel solution, an engineering safety and justification report is to be submitted. The engineering safety and justification report is to demonstrate how the proposed solution will satisfy the functional requirements and performance requirements in *Vol 2, Pt 9, Ch 9, 1 Functional requirements*.

3.1.3 The Naval Administration may impose requirements additional to those in this Chapter.

■ *Section 4* Fire detection and fire alarm systems

4.1 General

4.1.1 Fire detection and alarm systems are to comply with *Chapter 9 – Fixed fire detection and fire alarm systems* of the *Fire Safety Systems Code (FSS Code)* and *Vol 2, Pt 9, Ch 9, 4.1 General 4.1.3* to *Vol 2, Pt 9, Ch 9, 4.1 General 4.1.15*.

4.1.2 Fire detection control units, indicating panels, detector heads, manual call points and short-circuit isolation units are to be Type Approved in accordance with Test Specification Number 1 given in LR's Type Approval System for an environmental category appropriate for the locations in which they are intended to operate. For addressable systems, *see also Vol 2, Pt 9, Ch 8, 5 Programmable electronic systems (PES)*.

4.1.3 An audible fire-alarm is to be provided having a characteristic tone distinguishing it from the alarm system required by *Vol 2, Pt 9, Ch 7, 4.3 Alarm systems, general requirements* or any other alarm system. The audible fire-alarm is to be immediately audible throughout the machinery spaces, the navigating bridge and at manned watch positions as designated by the specified fire safety standard. Facilities are to be provided in the fire detection system to initiate manually the fire-alarm from positions adjacent to all exits from machinery spaces, the navigating bridge and manned watch positions as designated by the specified fire safety standard.

4.1.4 Fire detection and alarm systems are to be provided with at least two power supplies. One supply is to be connected to the main source of electrical power and another supply is to be connected to the emergency source of electrical power required by *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power*, or an accumulator battery capable of supplying power for the same period of time as the emergency source of electrical power. All power supply feeders for fire detection and alarm systems are to be in accordance with *Vol 2, Pt 9, Ch 3, 8.6 Conductor size 8.6.4*.

4.1.5 Automatic changeover facilities in accordance with *Vol 2, Pt 9, Ch 3, 4.3 Isolation and switching 4.3.4* are to be located in, or adjacent to, the main fire-control panel. Power supply changeover is to be achieved without adverse effect. Failure of any power supply is to operate an audible and visual alarm. *See also Vol 2, Pt 9, Ch 3, 8.10 Cable support systems 8.10.6 Vol 2, Pt 9, Ch 3, 8.10 Cable support systems 8.10.7* and *Vol 2, Pt 9, Ch 1, 2.5 Operation under fire conditions*.

4.1.6 Where an accumulator battery provides a power supply, on restoration of the main source of electrical power, the rating of the charge unit is to be sufficient to recharge the battery while maintaining the output supply to the fire detection and alarm system.

4.1.7 Power supplies from the main and emergency switchboards are to be supplied by separate feeders that are reserved solely for this purpose. Where the emergency feeder for the electrical equipment used in the operation of the fixed fire detection and alarm system is supplied from the emergency switchboard, it is to be run from this switchboard to the automatic changeover switch without passing through any other switchboard.

4.1.8 The fixed fire detection and fire-alarm systems are to be capable of remotely and individually identifying each detector and manually operated call point. At least one indicating unit is to be so located that it is easily accessible to responsible members of the crew. One indicating unit is to be located on the navigating bridge if the control panel is located in the central control station.

4.1.9 A loop circuit of an addressable fire detection system, capable of remotely identifying from either end of the loop each detector and manually operated call point served by the circuit, may serve spaces on both sides of the ship and on several decks, but is not to be situated in more than one main vertical or horizontal fire zone, nor is a loop circuit which covers an accommodation space, service space and/or control station to include a machinery space of Category A.

4.1.10 A loop circuit of an addressable fire detection system may comprise one or more sections. Where the loop comprises more than one section, the sections are to be separated by devices which will ensure that, if a short-circuit occurs anywhere in the loop, only the affected section will be isolated from the control panel. No section of detectors and manually operated call points is, in general, to include more than 50 detectors.

4.1.11 Detectors and manually operated call points are to be grouped into sections. The activation of any detector or manually operated call point is to initiate a visual and audible fire-alarm signal at the control panel and indicating units.

4.1.12 A section of detectors of an addressable fire detection system is neither to serve spaces on both sides of the ship nor on more than one deck, except that:

4.1.13 a section of detectors may serve spaces on more than one deck if those spaces are located in either the fore and aft end of the ship or they constitute common spaces occupying several decks, i.e. personnel spaces, enclosed stairways, etc.

4.1.14 in ships of less than 20 m in breadth, a section of detectors may serve spaces on both sides of the ship.

4.1.15 A section of fire detectors and manually operated call points of an addressable system is not to be situated in more than one main vertical zone.

4.1.16 A section of fire detectors and manually operated call points which covers a control station, a service space or an accommodation space is not to include a machinery space of Category A.

4.1.17 The wiring for each section of detectors and manually operated call points in an addressable fire detector system is to be separated as widely as practicable from that of all other sections on the same loop.

4.1.18 When it is intended that a particular loop is to be temporarily switched off, this state is to be clearly indicated at the fire detection indicating panels.

4.1.19 An audible fire-alarm is to be provided having a characteristic tone distinguishing it from any other alarm system. Facilities are to be provided in the fire detection system to initiate manually the fire-alarm from positions adjacent to all exits from machinery spaces, the navigating bridge and manned watch positions as designated by the Naval Administration.

4.1.20 Activation of any detector or manually operated call point in a machinery space is to result in immediate activation of the audible fire alarm throughout that machinery space, the navigating bridge and at manned watch positions as designated by the Naval Administration.

4.1.21 The activation of any detector or manually operated call point is to initiate a visual and audible fire-alarm signal at the control panel and indicating units. If the signals have not received attention within two minutes an audible alarm is to be automatically sounded throughout the crew accommodation and service spaces, control stations and machinery spaces of Category A. This alarm sounder system need not be an integral part of the detection system.

4.1.22 The fixed fire detection system is to be capable of remotely and individually identifying each detector and manually operated call point. At least one indicating unit is to be so located that it is easily accessible to responsible members of the crew. One indicating unit is to be located on the navigating bridge if the control panel is located in the central control station.

4.1.23 The fire alarm system is to be designed with self-monitoring properties. Power or system failures are to initiate an audible alarm distinguishable from the fire-alarm. This alarm may be incorporated in the machinery alarm system as required by *Vol 2, Pt 9, Ch 7, 4.3 Alarm systems, general requirements*.

4.1.24 Where it is intended that detectors be installed in external locations, in addition to meeting the requirements for an environmental category suitable for open decks, *see Vol 2, Pt 9, Ch 9, 4.1 General 4.1.26*, they are also to be tested for sun irradiation and ultraviolet exposure with satisfactory results.

4.1.25 When fire detectors are provided with means to adjust their sensitivity, the arrangements are to be such that the set point can be fixed and readily identified.

4.1.26 The fire detector heads are to be of a type which can be tested and reset without the renewal of any component. Facilities are to be provided on the fire-control panel for functional testing and reset of the system.

4.1.27 When it is intended that a particular detector(s) is to be temporarily switched off locally, this state is to be clearly indicated at the local position. Reactivation of the detector(s) is to be performed automatically after a preset time.

4.1.28 It is to be demonstrated to the Surveyor's satisfaction that detector heads are so located that air currents will not render the system ineffective whether the ship is at sea or in port.

4.1.29 Detector heads are to be located in the machinery spaces so that all potential fire outbreak points are guarded. A combination of detectors is to be provided to ensure that the system will react to all possible fire characteristics.

4.1.30 Fire detection indicating panels are to denote the section in which a detector or manually operated call point has operated. At least one indicating panel is to be located on the navigating bridge unless specified otherwise by the Naval Administration.

4.1.31 A fire detection control unit is to be located in the navigating bridge area, the fire-control station, or in some other position such that a fire in the machinery spaces will not render it inoperable.

4.1.32 Clear information is to be displayed on or adjacent to each indicating unit about the spaces covered and the location of the section and, for passenger ships, each detector and manually operated call point.

4.1.33 The fire detection system is not to be used for any other purpose, except that closing of fire doors and similar functions may be permitted at the control panel.

4.1.34 Sound signal equipment, fire and general alarm bells are to be supplemented by visual indication, areas having high levels of background noise, such as machinery spaces.

■ *Section 5*
Fire safety systems

5.1 Automatic sprinkler system

5.1.1 Any electrically driven power pump, provided solely for the purpose of continuing automatically the discharge of water from the sprinklers, is to be brought into action automatically by the pressure drop in the system before the standing fresh water charge in the pressure tank is completely exhausted.

5.1.2 Electrically driven sea-water pumps for automatic sprinkler systems are to be served by not less than two circuits reserved solely for this purpose, one fed from the main switchboard and one from the emergency switchboard. Such feeders are to be connected to an automatic change-over switch situated near the sprinkler pump and the switch is to be normally closed to the feeder from the main source of electrical power. No other switches are permitted in the feeders. The switches on the main and emergency switchboards are to be clearly labelled and normally kept closed.

5.1.3 Feeders for the sea-water pump and the automatic alarm and detection system are to be arranged so as to avoid galleys, machinery spaces and other enclosed spaces of high fire risk, except in so far as it is necessary to reach the appropriate switch boards. The cables are to be of a fire resistant type where they pass through such high risk areas.

5.1.4 The automatic alarm and detection system is to be fed by exclusive feeders from two sources of electrical power, one of which is to be an emergency source, with automatic change-over facilities located in, or adjacent to, the main alarm and detection panel.

5.1.5 For design guidance on electrical and fire protection systems in magazines, refer to *Vol 1, Pt 4, Ch 1, 6.8 Piping, cabling and electrical systems* and *Vol 1, Pt 4, Ch 1, 6.9 Fire protection*.

5.2 Fixed water-based local application fire-fighting systems

5.2.1 Where fixed water-based local application firefighting systems are installed in machinery spaces of category A in addition to the main fixed fire-extinguishing system to protect the fire hazard portions of machinery, the arrangements are to be in accordance with this sub-Section.

5.2.2 Where fixed water-based local application fire-fighting system pressure sources are reliant on external power they need only be supplied by the main source of electrical power.

5.2.3 The fire detection, control and alarm systems are to be provided with an emergency source of electrical power required by *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power* or *Vol 2, Pt 9, Ch 2, 5.3 Starting arrangements* and are also to be connected to the main source of electrical power. Separate feeders, reserved solely for this purpose, with automatic changeover facilities located in, or adjacent to, the main control panel are to be provided.

5.2.4 Failure of any power supply is to operate an audible and visual alarm. *See also Vol 2, Pt 9, Ch 3, 8.10 Cable support systems 8.10.6* and *Vol 2, Pt 9, Ch 3, 8.10 Cable support systems 8.10.7* and *Vol 2, Pt 9, Ch 1, 2.5 Operation under fire conditions*.

5.2.5 Means to activate a system are to be located at easily accessible positions inside and outside the protected space. Arrangements inside the space are to be situated such that they will not be cut off by a fire in the protected areas and are suitable for activation in the event of escape. Where it is proposed to install local activation means outside of the protected space, details are to be submitted for consideration.

5.2.6 Where the System Design Description requires automatic shutdown and/or isolation of protected machinery and equipment in adjacent areas in the event of system activation, evidence is to be submitted to demonstrate compliance with *Vol 2, Pt 9, Ch 9, 5.2 Fixed water-based local application fire-fighting systems 5.2.3*. This submission is to address:

- the failure effects of automatic shutdown and/or isolation measures on the machinery, equipment and the complete installation;
- the measures provided to prevent the loss of electrical power;
- the measures provided to prevent a reduction of the manoeuvrability of the ship; and
- the measures provided to ensure continued operation of the activated system.

The submission is to detail:

- permitted operating configurations while propulsion and steering machinery is operating;
- temporary interruptions in power supply while in port and
- power restoration measures following automatic shutdown and/or isolation of machinery or equipment.

See also Vol 2, Pt 9, Ch 9, 5.2 Fixed water-based local application fire-fighting systems 5.2.11.

5.2.7 System zones and protected areas are to be arranged to allow Mobility and/or Ship Type systems to be provided by machinery and/or equipment located outside areas affected by direct spray or extended water in the event of a system activation, where the machinery and/or equipment is duplicated or otherwise replicated to provide redundancy.

5.2.8 A control panel is to be provided for managing actions such as opening of valves, starting of pumps and initiation of alerts, and processing information from detectors. This panel is to be independent of the fire detection control unit required by *Vol 2, Pt 9, Ch 9, 4.1 General*.

5.2.9 Alarms are to be initiated upon activation of a system and are to indicate the specific zone activated at the control panel. Alarms are to be provided in each protected space, at an attended machinery control station and in the wheelhouse. The audible signal is to be distinguishable from other safety system signals.

5.2.10 A failure in a manual system activation switch circuit is not to prevent system activation using other installed manual system activation switches or, where installed, automatic activation. The means of activation are to be provided with self-monitoring facilities that will activate an alarm at an attended control station in the event of failure detection.

5.2.11 For the electrical safety of electrical and electronic equipment in areas protected by fixed water-based local application fire-fighting systems and adjacent areas where water may extend, the requirements of *Vol 2, Pt 9, Ch 9, 5.2 Fixed water-based local application fire-fighting systems 5.2.12* apply. *See also Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.14*.

5.2.12 As far as is practicable, electrical and electronic equipment is not to be located within protected areas or adjacent areas. The system pump, its electrical motor and the sea valve, if any, may be in a protected space provided that they are outside areas where water or spray may extend.

5.2.13 High voltage equipment and their enclosures are not to be installed in protected areas or adjacent areas. For high voltage generator enclosures which cannot be fully located outside of adjacent areas due to close proximity, a technical justification, including proposed degree of protection ratings that are normally not to be lower than IP54, may be submitted for consideration that demonstrates the overall safety of the installation in the event of system operation.

5.2.14 In addition to the degree of protection requirements of *Vol 2, Pt 9, Ch 1, 2.2 Design, construction and location 2.2.6*, electrical and electronic equipment enclosures located within protected areas and within adjacent areas are to provide adequate protection in the event of system operation.

5.2.15 To demonstrate compliance with *Vol 2, Pt 9, Ch 9, 5.2 Fixed water-based local application fire-fighting systems 5.2.14*, evidence of the suitability of electrical and electronic equipment for use in protected areas and adjacent areas is to be submitted in accordance with *Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.14* and *Vol 2, Pt 1, Ch 3, 5.12 Machinery enclosures 5.12.2*. The evidence is to demonstrate that additional precautions have been taken, where necessary, in respect of:

(a) satisfying *Vol 2, Pt 9, Ch 9, 5.2 Fixed water-based local application fire-fighting systems 5.2.12* and *Vol 2, Pt 9, Ch 9, 5.2 Fixed water-based local application fire-fighting systems 5.2.13*;
(b) the damage control and fire-fighting policy of the Navy or Naval Administration, *see Vol 2, Pt 1, Ch 3, 4.1 Availability for operation 4.1.6*;
(c) personnel protection against electric shock; and
(d) cooling airflow, where necessary, for equipment required to operate during system operation;
(e) maintenance requirements for equipment before return to operation following system activation.

Any test evidence submitted is to consider the overall installation, including equipment types, system configuration and nozzles and the potential effects of airflows in the protected space.

5.2.16 The evidence required by *Vol 2, Pt 9, Ch 9, 5.2 Fixed water-based local application fire-fighting systems 5.2.15* is to demonstrate the safe and effective operation of the overall arrangements in the event of system operation. This evidence is to demonstrate that exposure to system spray and/or water:

- cannot result in loss of Mobility or Ship Type systems (e.g. unintended activation of automatic machinery shutdown);
- cannot result in loss of availability of emergency services;
- will not affect the continued safe and effective operation of electrical and electronic equipment required to operate during the required period of system operation;
- does not present additional electrical or fire hazards; and
- would require only identified readily replaceable components to be repaired or replaced.

The installation of electrical and electronic equipment required to provide Mobility systems, Ship Type systems, or emergency services in enclosures with a degree of protection less than IP44 within areas exposed to direct spray is to be acceptable to LR, and evidence of suitability is to be submitted accordingly.

5.2.17 Fixed water-based local application fire-fighting system electrically-driven pumps may be shared with:

- equivalent automatic sprinkler systems;
- equivalent main machinery space fire-fighting systems; or
- local fire-fighting systems for deep-fat cooking equipment;

provided that the shared use is accepted by the Navy or Naval Administration as complying with their applicable regulations within the specified fire safety standard and the arrangements comply with the requirements of *Vol 2, Pt 9, Ch 9, 5.2 Fixed water-based local application fire-fighting systems 5.2.18*.

5.2.18 Shared electrically-driven sea-water pumps are to be served by not less than two circuits reserved solely for this purpose, one fed from the main source of electrical power and one from the emergency source of electrical power. Such feeders are to be connected to an automatic changeover switch situated near the pumps and the switch is to be normally closed to the feeder from the main source of electrical power. No other switches are permitted in the feeders. The switches on the main and emergency switchboards are to be clearly labelled and normally kept closed.

5.2.19 Failure of a component in the power and control system is not to result in a reduction of the total available pump capacity below that required by any of the areas the system is required to protect. For equivalent automatic sprinkler systems, a failure is not to prevent automatic release capability or reduce overall sprinkler pump capacity by more than 50 per cent.

5.2.20 Where fire-fighting systems share fire-fighting pumps, failure of one system is not to prevent activation of the pumps by any other system.

5.2.21 The activation of a system is not to result in loss of electrical power or reduction of the manoeuvrability of the ship and is not to require confirmation of space evacuation or sealing, *see also Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.14* and *Vol 2, Pt 9, Ch 9, 5.2 Fixed water-based local application fire-fighting systems 5.2.18*.

5.2.22 Systems installed in periodically unattended machinery spaces are to, additionally, be capable of automatic release and the arrangements are to be in accordance with *Vol 2, Pt 9, Ch 9, 5.2 Fixed water-based local application fire-fighting systems 5.2.23*.

5.2.23 A minimum of two fire detectors is to be provided for each protected area. One is to be a flame detector and the other is to be a smoke or heat detector, as considered appropriate to the nature of the risk and ambient conditions. The system is to be activated upon detection by two of the detectors. A fault in one detector is to initiate an alarm at an attended control station and is not to inhibit activation of the system under the control of the other detector or manually. Detector faults are not to cause activation of the system.

5.2.24 The fire detectors are to be arranged (located, oriented, guarded, etc.) to ensure that a fire in one protected area will not result in the inadvertent automatic activation of a system for another protected area. Guards or barriers provided to comply with this requirement are not to reduce the ability to detect a fire in the protected area.

5.2.25 A fire detection alarm system panel in accordance with *Vol 2, Pt 9, Ch 9, 4.1 General* may be used for receiving fire detection signals. Separate loops are not required provided that the address of the initiating device can be identified at the control panel. The received signals are then to be sent to the control panel required by *Vol 2, Pt 9, Ch 9, 5.2 Fixed water-based local application fire-fighting systems 5.2.8* for processing and action.

5.2.26 The system's fire detection systems and control units are to meet the performance criteria of SOLAS Ch II/C, Reg. 7 and are to be Type Approved in accordance with *Test Specification Number 1* given in LR's *Type Approval System* for an environmental category appropriate for the locations in which they are intended to operate.

5.3 Fire pumps

5.3.1 When the emergency fire pump is electrically driven, the power is to be supplied by a source other than that supplying the main fire pumps. This source is to be located outside the machinery spaces containing the main fire pumps and their source of power and drive units.

5.3.2 The cables to the emergency fire pump are not to pass through the machinery spaces containing the main fire pumps and their source of power and drive units. The cables are to be of a fire resistant type where they pass through other high fire risk areas.

5.4 Refrigerated liquid carbon dioxide systems

5.4.1 Where there are electrically driven refrigeration units for carbon dioxide fire-extinguishing systems, one unit is to be supplied by the main source of electrical power and the other unit from the emergency source of electrical power.

5.4.2 Each electrically driven carbon dioxide refrigerating unit is to be arranged for automatic operation in the event of loss of the alternative unit.

5.5 Fire safety stops

5.5.1 Means of stopping all ventilating fans, with manual reset, are to be provided, outside the spaces being served, at positions which will not readily be cut off in the event of a fire. The provisions for machinery spaces are to be independent of those for other spaces.

5.5.2 Machines driving forced and induced draught fans, and independently driven oil pumps for fuel, lubricating, hydraulic or refuelling oil, or other dangerous fluids are to be fitted with remote controls, with manual reset, situated outside the space concerned so that they may be stopped in the event of fire arising in the space in which they are located.

5.5.3 All power ventilation systems, machinery space ventilation, which is to be in accordance with *Vol 2, Pt 9, Ch 9, 5.5 Fire safety stops 5.5.2* are to be fitted with master controls, with manual reset, so that all fans may be stopped, in the event of fire, from the central control station and from another position situated as far apart as is practicable. Off indication is to be provided for the ventilation fans at the central control station along with provisions to enable them to be reactivated.

5.5.4 Means of cutting off all electrical power to the galley except lighting circuits, in the event of a fire, are to be provided outside the galley exits, at positions which will not readily be rendered inaccessible by such a fire. Consideration may be given to

relaxing this requirement for supplies to equipment not used for heating or cooking (e.g. alarm and clock systems) that do not present an electrical shock risk to fire-fighting personnel.

5.5.5 Fire safety stop systems are to be designed on the fail-safe principle or alternatively the power supplies to, and the circuits of, the fire safety stop systems are to be continuously monitored and an alarm initiated in the event of a fault. Cables are to be of a fire resistant type, *see Vol 2, Pt 9, Ch 3, 8.5 Construction 8.5.3* and *Vol 2, Pt 9, Ch 3, 4.2 Essential services 4.2.1*.

5.5.6 Exhaust ducts from main laundries are to be fitted with additional remote control arrangements for shutting off the exhaust fans and supply fans from within the space and for operating fire dampers, where fitted, at the lower end of the duct.

5.6 Fire doors

5.6.1 The electrical power required for the control, indication and alarm circuits of fire doors is to be provided by an emergency source of electrical power as required by *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power*. An alternative supply fed from the main source of electrical power, with automatic change-over facilities, is to be provided at the central control station. Failure of any power supply is to operate an audible and visual alarm, *see also Vol 2, Pt 9, Ch 3, 8.10 Cable support systems 8.10.6* and *Vol 2, Pt 9, Ch 1, 2.5 Operation under fire conditions*.

5.6.2 The control and indication systems for the fire doors are to be designed on the fail-safe principle with the release system having a manual reset.

5.7 Fire dampers

5.7.1 The electrical power required for the control and indication circuits of fire dampers is to be supplied from the emergency source of electrical power.

5.7.2 The control and indication systems for the fire dampers are to be designed on the fail-safe principle with the release system having a manual reset.

5.7.3 Fire dampers fitted at the lower end of exhaust ducts from main laundries are to be capable of automatic and remote operation.

5.8 Fire extinguishing media release

5.8.1 Where it is required that alarms be provided to warn of the release of a fire-extinguishing medium, and these are electrically operated, they are to be provided with an emergency source of electrical power, as required by *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power*, and also connected to the main source of electrical power, with automatic changeover facilities located in, or adjacent to, the fire-extinguishing media release panel, *see also Vol 2, Pt 9, Ch 3, 8.10 Cable support systems 8.10.6* and *Vol 2, Pt 9, Ch 3, 8.10 Cable support systems 8.10.7*. Failure of any power supply is to operate an audible and visual alarm, *see also Vol 2, Pt 9, Ch 3, 8.10 Cable support systems 8.10.6* and *Vol 2, Pt 9, Ch 3, 8.10 Cable support systems 8.10.7* and *Vol 2, Pt 9, Ch 1, 2.5 Operation under fire conditions*.

5.8.2 The arrangements for accessing and activating the release of fire extinguishing media are not to automatically shut off fuel oil, lubricating oil or hydraulic oil to Mobility machinery required for the propulsion and the safety of the ship, *see Vol 2, Pt 1, Ch 1, 3.1 Categories 3.1.5*.

5.9 Watertight doors

5.9.1 The electrical power required for power-operated sliding watertight doors is to be separate from any other power circuit and supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the bulkhead deck. The associated control, indication and alarm circuits are to be supplied from the emergency switchboard either directly or by a dedicated distribution board situated above the bulkhead deck and be capable of being automatically supplied by the transitional source of emergency electrical power required by *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power 5.2.6* in the event of failure of either the main or emergency source of electrical power.

5.9.2 Where the sources for opening and closing the watertight doors have electric motors, unless an independent temporary source of stored energy is provided, the electric motors are to be capable of being automatically supplied from the transitional source of emergency electrical power.

5.9.3 A single failure in the power operating or control system of power-operated sliding watertight doors is not to result in a closed door opening or prevent the hand operation of any door.

5.9.4 Availability of the power supply is to be continuously monitored at a point in the electrical circuit adjacent to the door operating equipment. Loss of any such power supply is to activate an audible and visual alarm at the central operating console at the navigating bridge.

5.9.5 Electrical power, control, indication and alarm circuits are to be protected against fault in such a way that a failure in one door circuit will not cause a failure in any other door circuit. Short circuits or other faults in the alarm or indicator circuits of a door are not to result in a loss of power operation of the door. Arrangements are to be such that leakage of water into the electrical equipment located below the bulkhead deck will not cause the door to open.

5.9.6 The enclosures of electrical components necessarily situated below the bulkhead deck are to provide suitable protection against the ingress of water with ratings as defined in IEC 60529: *Degrees of protection provided by enclosures (IP Code)* or an acceptable and relevant National Standard, as follows:

(a) Electrical motors, associated circuits and control components, protected to IPX7 standard.
(b) Door position indicators and associated circuit components protected to IPX8 standard, where the water pressure testing of the enclosures is to be based on the pressure that may occur at the location of the component during flooding for a period of 36 hours.
(c) Door movement warning signals, protected to IPX6 standard.

5.9.7 Watertight door electrical controls including their electric cables are to be kept as close as is practicable to the bulkhead in which the doors are fitted and so arranged that the likelihood of them being involved in any damage which the ship may sustain is minimised.

5.9.8 An audible alarm, distinct from any other alarm in the area, is to sound whenever the door is closed remotely by power and sound for at least five seconds but no more than ten seconds before the door begins to move and is to continue sounding until the door is completely closed. The audible alarm is to be supplemented by an intermittent visual signal at the door in crew areas and areas where the noise level exceeds 85 dB(A).

5.9.9 The door is to have an approximately uniform rate of closure under power. The closure time, from the time the door begins to move to the time it reaches the completely closed position, shall in no case be less than 20 seconds or more than 40 seconds with the ship in the upright position.

5.9.10 Sliding watertight doors are to be capable of being remotely closed from the bridge and are also to be operable locally from each side of the bulkhead. Indicators are to be provided at the respective control positions showing whether the doors are open or closed, and an audible alarm is to be provided at the door closure.

5.9.11 A central operating console is to be fitted on the navigating bridge and is to be provided with a 'master-mode' switch having:

(a) an 'in port' mode, which is to allow any door to be locally opened and locally closed after use without automatic closure; and
(b) an 'at sea' mode, which is to allow any door that is opened to be automatically closed whilst still permitting any doors to be locally opened but with automatic reclosure upon release of the local control mechanism.

5.9.12 The 'master mode' switch is to be arranged to be normally in the 'at sea' mode position; be clearly marked as to its function and be Type Approved in accordance with LR's Procedure for Type Approved Products.

5.9.13 The central operating console at the navigating bridge is to be provided with a diagram showing the location of each door, with visual indicators to show whether each door is open or closed. A red light is to indicate a door is fully open and a green light, a door fully closed. When the door is closed remotely a red light is to indicate the intermediate position by flashing. The indicating circuit is to be independent of the control circuit for each door.

5.9.14 The arrangements are to be such that it is not possible to remotely open any door from the central operating console.

5.10 Bow, stern and shell doors, loading doors and other closing appliances

5.10.1 Where it is required by *Vol 1, Pt 4, Ch 3 Special Features* that indicators be provided for bow, stern and shell doors, loading doors and other closing appliances, which are, intended to ensure the watertight integrity of the ships structure in which they are located, the indicator system is to be designed on the fail-safe principle. The system is to indicate if any of the doors or closing appliances are open or are not fully closed or secured.

5.10.2 Where such doors and appliances are to be operated at sea, the requirements of *Vol 2, Pt 9, Ch 9, 5.9 Watertight doors* are to be complied with as far as is practicable.

5.10.3 The electrical power supply for the indicator system is to be independent of any electrical power supply for operating and securing the doors.

Scope

The requirements of this Chapter are applicable to the design and construction philosophy for the Internal Communication system.

This Chapter details the requirements for sub-systems and equipment within the boundary of the Internal Communication system.

Approval will be in respect of the integrity of the Internal Communication System (including secondary and emergency communications), communication system configuration, EMC enclosure configuration (where appropriate), control, monitoring, alert and safety systems, and other critical support systems.

The Internal Communication system is to be designed and manufactured in accordance with a relevant International or National Standard acceptable to Lloyd's Register (hereinafter referred to as 'LR').

Application of this Chapter will facilitate the verification of the performance requirements of *ANEP-77 NATO Naval Ship Code*, Chapter VII, Regulation 10 and Chapter VIII, Regulation 7.

Section 1
Functional requirements

1.1 Functional requirements

1.1.1 A main broadcast system shall enable verbal communication to Persons Onboard of an emergency incident and the actions to be taken.

1.1.2 A General Emergency Alarm System shall enable the notification of all embarked persons in a timely manner that an emergency situation exists.

Section 2
Performance requirements

2.1 Performance requirements

2.1.1 The main broadcast system shall:

(a) allow one-way verbal communication to Persons Onboard;
(b) be clearly noticeable by all embarked persons;
(c) be easily distinguishable and recognisable;

(d) be continuously available;

(e) be protected from hazards such as fire, vibration, electrical interference or flooding;

(f) be provided such that any incident which may cause alarm failure shall be guarded against by system or equipment redundancy;

(g) be operable from strategic positions and locations used for command and control.

2.1.2 The general emergency alarm shall:

(a) be clearly noticeable by all embarked persons;

(b) be easily distinguishable and recognisable;

(c) be continuously available;

(d) be protected from hazards such as fire, vibration, electrical interference, flooding;

(e) be provided such that any incident which may cause alarm failure shall be guarded against by system or equipment redundancy;

(f) be operable from strategic positions.

2.1.3 Effective means of communicating orders from the conning positions to any position from which the speed and direction of thrust of the propellers can be controlled shall be provided.

■ *Section 3* Verification requirements

3.1 General

3.1.1 Compliance with the requirements in *Vol 2, Pt 9, Ch 10, 4 Main broadcast* inclusive is deemed to satisfy the functional requirements and performance requirements above.

3.1.2 Where a designer offers a novel solution, an engineering safety and justification report is to be submitted. The engineering safety and justification report is to demonstrate how the proposed solution will satisfy the functional requirements and performance requirements in *Vol 2, Pt 9, Ch 10, 1 Functional requirements*.

3.1.3 The Naval Administration may impose requirements additional to those in this Chapter.

■ *Section 4* Main broadcast

4.1 Crew and embarked personnel address system

4.1.1 Crew and embarked personnel address systems are to comply with the *International Lifesaving-Saving Appliances (LSA) Code* and the requirements of this Section.

4.1.2 The crew and embarked personnel address system is to be provided with an emergency source of electrical power as required by *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power* and also connected to the main source of electrical power with automatic changeover facilities located adjacent to the crew and embarked personnel address system. Failure of any power supply is to operate an audible and visual alarm, *see also Vol 2, Pt 9, Ch 3, 8.10 Cable support systems 8.10.6* and *Vol 2, Pt 9, Ch 1, 5.2 Centralised control station for machinery*.

4.1.3 The crew and embarked personnel address system is to have multiple amplifiers having their power supplies so arranged that a single fault, fire or casualty will not cause the loss of the facility to broadcast emergency announcements in crew and embarked personnel rooms, alleyways, stairways and control stations, albeit at a reduced capacity.

4.1.4 The crew and embarked personnel address distribution system is to be so arranged that a fire or casualty in any one main vertical zone, other than the zone in which the crew and embarked personnel address control station is located, will not interfere with the facility to broadcast emergency announcements in any other such zone, *see also Vol 2, Pt 9, Ch 1, 2.6 Operation under flooding conditions*.

4.1.5 There are to be at least two cable routes in each fire zone sufficiently separated throughout their length to crew and embarked personnel rooms, alleyways, stairways, and control stations so arranged that any single electrical fault, localised fire or casualty will not cause the loss of the facility to broadcast emergency announcements in any crew and embarked personnel rooms, alleyways, stairways, and control stations, albeit at a reduced capacity.

4.1.6 Amplifiers are to be continuously rated for the maximum power that they are required to deliver into the system for audio and, where alarms are to be sounded through the crew and embarked personnel address system, for tone signals.

4.1.7 Loudspeakers are to be continuously rated for their proportionate share of amplifier output and protected against short-circuits.

4.1.8 Amplifiers and loudspeakers are to be selected and arranged to prevent feedback and other interference. There are also to be means to automatically override any volume controls, so as to ensure the specified sound pressure levels are met.

4.1.9 Where the crew and embarked personnel address system is used for sounding the general emergency alarm and the fire-alarm, the following requirements are to be met in addition to those of *Vol 2, Pt 9, Ch 10, 5.1 Emergency alarm system*:

(a) The emergency system is given automatic priority over any other system input.
(b) More than one device is provided for generating the sound signals for the emergency alarms.

4.1.10 Where more than one alarm is to be sounded through the crew and embarked personnel address system, they are to have recognisably different characteristics and additionally be arranged, so that any single electrical failure which prevents the sounding of any one alarm will not affect the sounding of the remaining alarms.

4.1.11 The sound pressure levels are to be measured during a practical test using speech and, where applicable, tone signals and documented, *see Vol 2, Pt 9, Ch 11, 1.2 Trials*

4.1.12 Sound signal equipment, fire and general alarm bells are to be supplemented by visual indications, in areas having high levels of background noise, such as machinery spaces.

■ *Section 5*
General emergency alarm

5.1 Emergency alarm system

5.1.1 An electrically operated bell or klaxon or air-operated whistle with independent air supply or other equivalent warning system installed in addition to the ship's whistle or siren, for sounding the general emergency alarm signal is to comply with the *International Lifesaving-Saving Appliances (LSA) Code* and with the requirements of this Section, *see also Vol 2, Pt 9, Ch 3, 8.10 Cable support systems 8.10.6* and *Vol 2, Pt 9, Ch 1, 2.5 Operation under fire conditions*.

5.1.2 The general emergency alarm system is to be provided with an emergency source of electrical power as required by *Vol 2, Pt 9, Ch 2, 5.2 Emergency source of electrical power* and *Vol 2, Pt 9, Ch 2, 5.3 Starting arrangements* and also connected to the main source of electrical power with automatic changeover facilities located in, or adjacent to, the main alarm signal distribution panel. Failure of any power supply is to operate an audible and visual alarm, *see also Vol 2, Pt 9, Ch 3, 8.10 Cable support systems 8.10.6*.

5.1.3 The general emergency alarm distribution system is to be so arranged that a fire or casualty in any one main vertical zone other than the zone in which the crew and embarked personnel address control station is located, will not interfere with the distribution in any other such zone.

5.1.4 There are to be segregated cable routes to crew and embarked personnel rooms, alleyways, stairways, and control stations, so arranged that any single electrical fault, localised fire or casualty will not cause the loss of the facility to sound the general emergency alarm in any crew and embarked personnel rooms, alleyways, stairways, and control stations, be it at a reduced capacity.

5.1.5 Where the special alarm fitted to summon the crew – operated from the navigation bridge, or fire-control station, forms part of the ship's general alarm system, it is to be capable of being sounded independently of the alarm to the passenger spaces.

5.1.6 The sound pressure levels are to be measured during a practical test and documented, *see Vol 2, Pt 9, Ch 11, 1.2 Trials*.

5.1.7 Sound signal equipment, fire and general alarm bells are to be supplemented by visual indications in areas having high levels of background noise, such as machinery spaces.

■ *Section 6* **Two-way communication**

6.1 Two-way communication is to be provided at key locations as defined by the Naval Administration.

Section 1
Testing and trials

1.1 Testing

1.1.1 Tests in accordance with *Vol 2, Pt 9, Ch 11, 1.1 Testing 1.1.2* are to be satisfactorily carried out on all electrical equipment, complete or in sections, at the manufacturer's premises and a test report issued by the manufacturer.

1.1.2 A high voltage at any frequency between 25 and 100 Hz is to be applied between:

(a) all current carrying parts connected together and earth;
(b) all current carrying parts of opposite polarity or phase.

For rotating machines the value of test voltage is to be 1000 V plus 2 x rated voltage with a minimum of 2000 V, and for other electrical equipment, it is to be in accordance with *Table 11.1.1 Test voltage*. Items of equipment included in the assembly for which a test voltage lower than the above is specified may be disconnected during the test and tested separately at the appropriate lower test voltage. The test is to be commenced at a voltage of about one-third the test voltage and is to be increased to full value as rapidly as is consistent with its value being indicated by the measuring instrument. The full test voltage is then to be maintained for 1 minute, and then reduced to one-third full value before switching off. The assembly is considered to have passed the test if no disruptive discharge occurs.

Table 11.1.1 Test voltage

Rated voltage, U_n U_n V	Test voltage a.c. (r.m.s.), V
$U_n \leq 60$	500
$60 < U_n \leq 1000$	$2 \times U_n + 1000$
$1000 < U_n \leq 2500$	6500
$2500 < U_n \leq 3500$	10000
$3500 < U_n \leq 7200$	20000
$7200 < U_n \leq 12000$	28000
$12000 < U_n \leq 15000$	38000

1.1.3 When it is desired to make additional high voltage tests on equipment which has already passed its tests, the voltage of such additional tests is to be 80 per cent of the test voltage the equipment has already passed.

1.1.4 Immediately after the high voltage test, the insulation resistance is to be measured using a direct current insulation tester, between:

(a) all current carrying parts connected together and earth;
(b) all current carrying parts of different polarity or phase.

The minimum values of test voltage and insulation resistance are given in *Table 11.1.2 Test voltage and minimum insulation*.

Table 11.1.2 Test voltage and minimum insulation

Rated voltage U_n V	Minimum voltage of the tests, V	Minimum insulation resistance, MΩ
$U_n \leq 250$	$2 \times U_n$	1

$250 < U_n \leq 1000$	500	1
$1000 < U_n \leq 7200$	1000	$\frac{U_n}{1000} + 1$
$7200 < U_n \leq 15000$	5000	$\frac{U_n}{1000} + 1$

1.1.5 Tests in accordance with the standard with which the equipment complies may be accepted as an alternative to the above.

1.2 Trials

1.2.1 Before a new installation, or any alteration or addition to an existing installation, is put into service the applicable trials in *Vol 2, Pt 9, Ch 11, 1.2 Trials 1.2.2* are to be carried out. These trials are in addition to any acceptance tests which may have been carried out at the manufacturer's works and are to be to the Surveyor's satisfaction. A report having the results of measurements taken during the trials is to be submitted for record purposes.

1.2.2 Means are to be provided to facilitate testing during normal machinery operation, e.g. by the provision of three-way test valves or equivalent.

1.2.3 Acceptance tests and trials for Programmable Electronic Systems are to include verification of software lifecycle activities appropriate to the stage in the system's lifecycle at the time of system examination. The documentation required by *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.8* is to be in accordance with the current configuration and the testing and trials are to address software modifications to the Surveyor's satisfaction.

1.2.4 Wireless data communication links are to be operational and tested during trials. Tests are to demonstrate that radio-frequency transmission does not interfere with the operation of equipment required by this Chapter or other Sections of the Rules and does not itself malfunction as a result of electromagnetic interference during expected operating conditions. Reversionary modes are to be activated to demonstrate continued safe and effective operation in the event of fault conditions.

1.2.5 The insulation resistance is to be measured of all circuits and electrical equipment, using a direct current insulation tester, between:

(a) all current carrying parts connected together and earth and, so far as is reasonably practicable;
(b) all current carrying parts of different polarity or phase.

The minimum values of test voltage and insulation resistance are given in *Table 11.1.2 Test voltage and minimum insulation* The installation may be subdivided and appliances may be disconnected if initial tests produce results less than these figures.

1.2.6 Tests are to be made to verify the effectiveness of:

(a) earth continuity conductor;
(b) the earthing of non-current carrying exposed metal parts of electrical equipment and cables not exempted by *Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding 2.4.2*;
(c) bonding for the control of static electricity.

1.2.7 It is to be demonstrated that the Rules have been complied with in respect of:

(a) satisfactory performance of each generator throughout a run at full rated load;
(b) temperature of joint, connections, circuit-breakers and fuses;
(c) the operation of engine governors, synchronising devices, overspeed trips, reverse-current, reverse-power and over-current trips and other safety devices;
(d) voltage regulation of every generator when full rated load is suddenly thrown off and when starting the largest motor connected to the system;
(e) voltage drop at the worst case condition;
(f) harmonic distortion of the voltage waveform, where declared;

(g) satisfactory parallel operation, and kW and KVA load sharing of all generators capable of being operated in parallel at all loads up to normal working load;
(h) all Mobility systems, Ship Type systems, and other important equipment are to be operated under service conditions, though not necessarily at full load or simultaneously, for a sufficient length of time to demonstrate that they are satisfactory;
(i) propulsion equipment is to be tested under working conditions and operated in the presence of the Surveyors and to their satisfaction. The equipment is to have sufficient power for going astern to secure proper control of the ship in all normal circumstances. The ability of the machinery to reverse the direction of thrust of the propeller in sufficient time, under normal manoeuvring conditions, and so bring the ship to rest from maximum ahead service speed, is to be demonstrated at the sea trial, *see also Vol 2, Pt 1, Ch 3, 16.3 Performance testing 16.3.7*;
(j) operation of power management for electric propulsion.

1.2.8 Measurements are to be taken as part of the trials specified in *Vol 2, Pt 9, Ch 11, 1.2 Trials 1.2.7*, *Vol 2, Pt 9, Ch 11, 1.2 Trials 1.2.7*, *Vol 2, Pt 9, Ch 11, 1.2 Trials 1.2.7* and *Vol 2, Pt 9, Ch 11, 1.2 Trials 1.2.7* to verify that the installation will provide a quality of power supply in accordance with the values listed in *Vol 2, Pt 9, Ch 1, 2.1 Quality of power supplies (QPS)*.

1.2.9 In addition to *Vol 2, Pt 9, Ch 11, 1.2 Trials 1.2.5*, unless it has been satisfactorily shown by the design verification and validation process required by *Vol 2, Pt 9, Ch 1, 3.2 General requirements 3.2.4*, that the power supply quality complies with the requirements of the specified standard, then compliance is to be demonstrated by measurements taken at representative ship operating loads, as defined by the Naval Administration, *see Vol 2, Pt 9, Ch 1, 3.1 General 3.1.1*.

1.2.10 It is to be demonstrated by practical tests that the Rules have been complied with in respect of fire, crew emergency and ship safety systems.

1.2.11 On completion of the general emergency alarm system and the crew and embarked personnel address system tests, the Surveyor is to be provided with two copies of the test schedule, detailing the measured sound pressure levels. Such schedules are to be signed by the Surveyor and the Builder.

1.3 High voltage cables

1.3.1 Before a new high voltage cable installation, or an addition to an existing installation, is put into service, a voltage withstand test is to be satisfactorily carried out on each completed cable and its accessories. The test is to be carried out after the insulation resistance test required by *Vol 2, Pt 9, Ch 11, 1.2 Trials 1.2.2* and may use either an a.c. voltage at power frequency or a d.c. voltage.

1.3.2 When an a.c. voltage withstand test is carried out, the voltage is to be not less than the normal operating voltage of the cable and it is to be maintained for a minimum of 24 hours.

1.3.3 When a d.c. voltage withstand test is carried out, the voltage is to be not less than:

(a) 1,6 (2,5U_o + 2 kV) for cables of rated voltages (U_o) up to and including 3,6 kV; or
(b) 4,2U_o for higher rated voltages where U_o is the rated power frequency voltage between conductor and earth or metallic screen, for which the cable is designed. The test voltage is to be maintained for a minimum of 15 minutes. After completion of the test the conductors are to be connected to earth for a sufficient period in order to remove any trapped electric charge. An insulation resistance test in accordance with *Vol 2, Pt 9, Ch 11, 1.2 Trials 1.2.2* is then to be repeated.

1.4 Hazardous areas

1.4.1 All electric equipment located in hazardous areas is to be examined to ensure that it is of a type permitted by the Rules, has been installed in compliance with its certification, and that the integrity of the protection concept has not been impaired.

1.4.2 Alarms and interlocks associated with pressurised equipment and the ventilation of spaces located in hazardous areas are to be tested for correct operation.

1.5 Unattended machinery space operation - UMS notation

1.5.1 In addition to the tests required by *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems* the suitability of the installation for operation in the unattended mode is to be demonstrated during sea trials observing the following:

(a) Occurring alarms and the frequency of operation both during steady steaming and under manoeuvring conditions using bridge control.
(b) Any intervention by personnel in the operation of the machinery.

1.6 Operation from a centralised control station - CCS notation

1.6.1 In addition to the tests required by *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems*, the suitability of the installation for operation from the centralised control station is to be demonstrated during sea trials.

1.7 Integrated platform management system failure

1.7.1 Where mobility type ship systems are operated through an Integrated Platform Management System (IPMS), a failure in the IPMS is not to render the ship's system inoperable. Reversionary modes of operation are to be provided to ensure safe and graceful degradation under these conditions. The Systems Design Description shall define the acceptable levels of degraded performance.

1.8 Record of trials

1.8.1 Two copies of the alarm and control equipment test schedules, as required by *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review 1.4.25*, signed by the Surveyor and Builder are to be provided on completion of the survey. One copy is to be placed on board the vessel and the other submitted to LR.

■ *Section 1 Scope*

1.1 The requirements of this Chapter are applicable to incorporate principles of human-centred design and ergonomics in the design and construction philosophy of control stations and ship-board lighting systems.

1.2 The requirements of this Chapter focus on the hazard associated with personnel at control stations and the related physical hazards and general and task lighting. Additionally a broader set of issues related to the cognitive aspects of control station design for both traditional and computer-based control is provided.

1.3 Application of this Chapter will facilitate the verification of the functional objectives and performance requirements of *ANEP-77 NATO Naval Ship Code*, Chapter IV, Regulation 17.

■ *Section 2*
Functional requirements

2.1 Functional requirements

2.1.1 Physical arrangements for machinery and equipment shall not pose a risk to personnel.

2.1.2 Information relating to the operation of the equipment shall not result in unintended actions.

■ *Section 3*
Performance requirements

3.1 Performance requirements

3.1.1 The following areas are to be designed with consideration to the human element:

(a) the Navigation Bridge;
(b) the main machinery control position; and
(c) other conning and control positions as agreed with the Naval Administration.

3.1.2 The layout of control positions is to enhance usability and reduce human error in Operators' tasks.

3.1.3 The working environment is to be designed to be safe, have the minimum of distractions, be sufficiently comfortable, help to maintain vigilance, and maximise communication amongst Operators at main control stations.

3.1.4 User interfaces are to be designed to enhance the usability of systems and equipment, reduce human error, enhance situational awareness, and support safe and effective monitoring and control under normal and foreseeably abnormal modes of operation.

3.1.5 The design of lighting is to facilitate visual task performance, Operator safety and visual comfort.

■ *Section 4* **Verification requirements**

4.1 General

4.1.1 An engineering safety and justification report is to be submitted to demonstrate the design incorporates the requirements of Sections *Vol 2, Pt 10, Ch 1, 2 Functional requirements*, *Vol 2, Pt 10, Ch 1, 3 Performance requirements*, *Vol 2, Pt 10, Ch 1, 5 Particulars to be submitted*, *Vol 2, Pt 10, Ch 1, 6 Ergonomics of control stations* and *Vol 2, Pt 10, Ch 1, 7 Ergonomics of lighting*.

4.1.2 The Naval Administration may impose requirements additional to those in this Chapter.

■ *Section 5* **Particulars to be submitted**

5.1 Particulars to be submitted

5.1.1 Plans showing the location and details of control stations, e.g. control panels and consoles, location and details of controls and displays on each panel.

5.1.2 Details of user interface specifications.

5.1.3 A general arrangement plan of control rooms showing the position of consoles, handrails, operator area, lighting, door and window arrangements.

5.1.4 Drawing of HVAC systems including vent arrangements.

5.1.5 A general arrangement plan for the ship showing lighting and window arrangements.

■ *Section 6* **Ergonomics of control stations**

6.1 Control station layout

6.1.1 In order to support operator tasks at control stations, enhance usability and reduce human error, the layout arrangements are to comply with the requirements set out in *Vol 2, Pt 10, Ch 1, 6.1 Control station layout 6.1.2*.

6.1.2 Control stations are to provide sufficient space and access for the intended number of Operators in the expected operating conditions.

6.1.3 Local control stations are to be positioned to minimise the risk of harm to the Operator.

6.1.4 Controls, displays and indicators are to be both logically and physically grouped according to their function.

6.1.5 Where a function may be accessed from more than one interface, the arrangement of displays and controls is to be consistent.

6.1.6 Frequently used controls and displays are to be within easy reach and visible to the Operator from the normal working position.

6.1.7 Controls and displays used infrequently and which may be used in an emergency are to be clearly identifiable, clearly visible, easily accessible and positioned to allow safe operability.

6.1.8 The relationship of a control with a display is to be immediately apparent.

6.1.9 The relationship of controls and displays with the equipment under control is to be immediately apparent.

6.1.10 There is to be adequate spacing between controls and between controls and obstructions.

6.1.11 Controls and their associated displays are to be located such that the information on the displays can be easily read during the operation of the controls.

6.1.12 Indicators related to controls are to be visible during their operation.

6.1.13 Instruments are to face the Operator’s intended working position.

6.2 Physical environment

6.2.1 In order to establish a working environment that has minimum distractions, is sufficiently comfortable, helps maintain vigilance and maximises communication amongst Operators at main control stations, the requirements of *Vol 2, Pt 10, Ch 1, 6.2 Physical environment 6.2.2* are to be complied with.

6.2.2 Control stations are to be positioned, as far as practicable, away from, or insulated against, sources of structurally transmitted vibration and noise, such as ventilation fans, engine intake fans and other noise sources.

6.2.3 In general, noise levels are to comply with IMO *Resolution MSC.337(91) – Adoption of the Code on Noise Levels on Board Ships – (Adopted on 30 November 2012)The Annex below is consolidated into Noise Levels - Code on Noise Levels on Board Ships (Resolution MSC.337(91))*, and take into account IMO Res. A.343(IX): *Recommendation on Methods of Measuring Noise. Levels at Listening Posts*.

6.2.4 Where provided, the heating, ventilation and air-conditioning system is to be capable of maintaining the temperature between 18°C and 27°C.

6.2.5 Where provided, the heating, ventilation and air-conditioning system should be capable of providing and maintaining a relative humidity within a range from 30 per cent minimum to 70 per cent maximum.

6.2.6 The flow of air from heating or air-conditioning systems is not to be guided directly to the Operator, or means are to be provided to adjust the direction of air flow from those systems.

6.2.7 Placement of controls, displays and indicators are to consider the position of light sources relative to the Operator with respect to reflections and evenness of lighting.

6.2.8 The level of lighting is to be sufficient to enable operation of user interfaces. Lighting levels in accordance with *Table 1.6.1 Specific lighting levels* will be considered to satisfy this requirement. *Vol 2, Pt 10, Ch 1, 7 Ergonomics of lighting* contains further requirements on internal and task lighting for the ship.

Table 1.6.1 Specific lighting levels

Work area	Ideal lux	Minimum lux
General lighting	540	220
Control room consoles (front)	540	320
Control room consoles (rear)	325	110
Local operating panels	540	320
Remote operating panels	540	320

6.2.9 Seating provided for use at control stations is to allow for varying height and/or reach needs of Operators. Seating arrangements are to minimise the need for twisting and/or turning motions by the Operator.

6.2.10 Physical hazards, such as sharp edges protuberances and trip hazards are to be avoided.

6.2.11 Sufficient hand-rails or equivalent are to be fitted to enable Operators to move and stand safely in rough seas.

6.2.12 Work surfaces are to be capable of withstanding oils and solvents common to ships and are to be easy to clean.

6.3 Operator interface

6.3.1 The requirements of *Vol 2, Pt 10, Ch 1, 6.3 Operator interface 6.3.2* apply to operator interfaces for Mobility and/or Ship Type engineering systems located either locally, remotely or within the main control room. The requirements are intended to enhance the usability of systems and equipment, reduce human error, enhance situational awareness and support safe and effective monitoring and control under normal and abnormal modes of operation.

6.3.2 The design of the operator interface is to permit the satisfactory monitoring, control and supervision of the machinery and equipment.

6.3.3 Information is to be presented to the Operator consistently both within and between different interfaces, *see Vol 2, Pt 10, Ch 1, 6.5 Displays 6.5.3*.

6.3.4 The response of the machinery and equipment to operator input is to be consistent between interfaces for the same function.

6.3.5 Visual, audible or mechanical feedback is to be provided to indicate that operator input has been acknowledged.

6.3.6 Functions requested by the Operator are to be confirmed by the displays on completion.

6.3.7 Indications and documentation are to be in English or the language of the crew.

6.4 Controls

6.4.1 The requirements of *Vol 2, Pt 10, Ch 1, 6.4 Controls 6.4.2* apply to operator interfaces for Mobility and/or Ship Type engineering systems located either locally, remotely or within the main control room. The requirements are intended to enhance the usability of systems and equipment, reduce human error, enhance situational awareness and support safe and effective monitoring and control under normal and abnormal modes of operation.

6.4.2 Operator inputs are to be checked for errors, for example, out of range data or incorrect actions, and alert the Operator when they occur.

6.4.3 Means to rapidly and safely correct wrong inputs or commands are to be provided.

6.4.4 Assistance is to be provided to the Operator to recover from operator errors, for example, through advisory screens where the automation system has this facility.

6.4.5 Operator confirmation is to be provided for any control action that could affect the safety of the ship, i.e. they should not rely on single keystrokes.

6.4.6 The purpose of each control is to be clearly indicated. Where standard symbols have been internationally adopted, they should be used.

6.4.7 The settings of mechanical controls are to be immediately evident.

6.4.8 The means of operation of mechanical controls is to be consistent with expectations.

6.4.9 Controls or combined controls and indicators are to be distinguishable from indicators.

6.4.10 Where control is provided by touch screens, the size of the soft keys are to be of a sufficient size for operation in areas where vibration occurs or gloves are likely to be worn.

6.4.11 Where virtual keypads/keyboards or dialogue boxes are used on touch screens, they are not to obscure status or alarm areas of the display.

6.4.12 Keyboards are to be divided logically into functional areas. Alphanumeric, paging and specific system keys are to be grouped separately.

6.4.13 The arrangement of controls that affect the safe operation of the ship should minimise the possibility of inadvertent operation.

6.5 Displays

6.5.1 The requirements of *Vol 2, Pt 10, Ch 1, 6.5 Displays 6.5.2* apply to operator interfaces for Mobility and/or Ship Type engineering systems located either locally, remotely or within the main control room. The requirements are intended to enhance the usability of systems and equipment, reduce human error, enhance situational awareness and support safe and effective monitoring and control under normal and abnormal modes of operation.

6.5.2 The displays and indicators are to present the Operator with clear, timely and relevant information.

6.5.3 Graphical symbols and colour coding are to be consistent. The graphical symbols of display functions are to be in accordance with a recognised International Standard, for example, ISO 14617(all parts): *Graphical symbols for diagrams*. Colour coding of functions and signals is to be in accordance with a recognised International Standard, for example, ISO 2412 *Shipbuilding – Colours of indicator lights*.

6.5.4 The symbols used in mimic diagrams for the services listed in *Vol 2, Pt 1, Ch 1, 3.1 Categories 3.1.5*, *Vol 2, Pt 1, Ch 1, 3.1 Categories 3.1.6* and *Vol 2, Pt 1, Ch 1, 3.1 Categories 3.1.7* are to be consistent across all displays.

6.5.5 The display of information is to be consistent with respect to screen layout and arrangement of information.

6.5.6 Flashing of information is to be reserved for unacknowledged alerts, or transient states, for example, valve moving.

6.5.7 The functions supported by a display are to be clearly indicated. For displays that can support multiple functions it is to be possible to select the display associated with the primary function or an overview by a simple operator action.

6.5.8 The operating mode of the machinery and equipment is to be clearly indicated.

6.5.9 In general, indications provided by instrumentation which are displayed digitally are not to change more frequently than twice per second.

6.5.10 To indicate an increasing value in a single direction, on a fixed circular scale, the pointer is to move clockwise. If the pointer is fixed, the scale is to move anticlockwise to indicate an increase in value.

6.5.11 To indicate an increasing value on a horizontal linear scale, the pointer is to move from left to right. On a vertical linear scale, the pointer is to move upwards to indicate an increase in value.

6.5.12 The pointer is not to obscure the numbers on the scale.

6.5.13 Alphanumeric data, text, symbols and other graphical information is to be readable from relevant operator positions under lighting conditions as specified in *Vol 2, Pt 9, Ch 6, 2.1 Performance requirements 2.1.9*. Character height in millimetres is to be not less than three and a half times the reading distance in metres and character width is to be 0,7 times the character height.

6.5.14 A simple sans-serif character font is to be used in displays. In descriptive text, lower case letters are to be used, where appropriate, as opposed to capitals to improve readability.

6.5.15 Where information related to the safe operation of machinery and equipment is provided, it is to be continuously available to the Operator.

6.5.16 Failures are to be indicated in a clear and unambiguous manner. Sufficient information is to be provided for the Operator to identify the cause of the failure.

■ *Section 7*
Ergonomics of lighting

7.1 Positioning and installation

7.1.1 In order to meet the ergonomic requirements of *Vol 2, Pt 10, Ch 1, 7.2 Luminance distribution* the positioning and installation of lights are to comply with *Vol 2, Pt 10, Ch 1, 7.1 Positioning and installation 7.1.2*.

7.1.2 Natural lighting through the use of windows and doors is to be provided as far as practicable.

7.1.3 Lights are to be positioned, as far as practicable, in the same horizontal plane and arranged symmetrically to produce a uniform level of illumination.

7.1.4 Lights are to be positioned so as to reduce bright spots and shadows as far as possible.

7.1.5 Lights are to be positioned taking account of structures such as beams and columns etc. so the lighting is not blocked by these items.

7.1.6 Lights are not to be positioned in locations which would result in limited illumination.

7.1.7 Lights are to be positioned taking account of air-conditioning vents or fans, fire detectors, water sprinklers, etc. so the lighting is not blocked by these items.

7.1.8 The position of lights configured to strips or tubes is, as far as practicable, to be at right angles to an Operator's line of sight while the Operator is located at their typical duty station.

7.1.9 Any physical hazards that provide a risk to operator safety are to be appropriately illuminated.

7.1.10 The position of lights is to consider the transfer of heat to adjacent surfaces.

7.1.11 Lights are to be positioned in locations that are easy to reach for bulb replacement or maintenance.

7.2 Luminance distribution

7.2.1 In order to provide even, fatigue-free illumination the requirements of *Vol 2, Pt 10, Ch 1, 7.2 Luminance distribution 7.2.2* to *Vol 2, Pt 10, Ch 1, 7.2 Luminance distribution 7.2.6* are to be complied with.

7.2.2 The light levels falling on the plane in which a task is performed, are to be suitable for the type of task, i.e. they are to consider the variation in the working planes.

7.2.3 Sharp contrasts in illumination levels across an operator task or working plane are to be avoided, as far as possible.

7.2.4 Sharp contrasts in illumination levels between an operator task area and the immediate surround and general background area are to be avoided, as far as possible.

7.2.5 Where required for operational tasks, local lighting is to be provided in addition to general lighting.

7.2.6 Lighting is to be free of perceived flicker.

7.3 Glare

7.3.1 In order to minimise glare (to avoid dazzle, discomfort and fatigue), the requirements of *Vol 2, Pt 10, Ch 1, 7.3 Glare 7.3.2* are to be complied with.

7.3.2 Lights are to be positioned so as to reduce as far as possible glare or high brightness reflections from working and display surfaces.

7.3.3 Lights are to be positioned so as to provide even illumination and minimal glare on controls, displays and indicators.

7.3.4 Where necessary, suitable blinds and shading devices are to be used to prevent glare.

7.3.5 Surfaces are to have a non-reflective or matt finish in order to reduce the likelihood of indirect glare.

7.3.6 Where a transparent cover is fitted over a control, display or indicator, it is to be designed to minimise reflections.

7.4 Location of lighting controls and outlets

7.4.1 In order to allow convenient use of lighting the requirements of *Vol 2, Pt 10, Ch 1, 7.4 Location of lighting controls and outlets 7.4.2* to *Vol 2, Pt 10, Ch 1, 7.4 Location of lighting controls and outlets 7.4.6* are to be complied with.

7.4.2 The lighting system is to be easily maintained and operated by personnel.

7.4.3 Lighting is to be controllable locally in accommodation and working areas, except where this conflicts with safety requirements.

7.4.4 Light switches are to be fitted in easily accessible locations where safe and effective operation is possible.

7.4.5 The mounting height of switches is to be such that personnel can reach switches with ease.

7.4.6 Power outlets are to be provided where temporary, local, task lighting will be required, except in hazardous areas.

7.5 Night vision

7.5.1 In order to maintain night vision and facilitate safety during hours of darkness, the requirements of *Vol 2, Pt 10, Ch 1, 7.5 Night vision 7.5.4* to *Vol 2, Pt 10, Ch 1, 7.5 Night vision 7.5.10* are to be complied with.

7.5.2 Lighting on the ship's superstructure is to be directed away from, and shaded to prevent direct illumination of, the bridge windows and lookout points. Attention is drawn to the requirements of International Regulations for Preventing Collisions at Sea (COLREGS) with regard to exhibition of lights other than navigation lights.

7.5.3 Lookout positions are to offer shading from direct illumination by off-ship operations.

7.5.4 A satisfactory level of lighting is to be available to enable members of the bridge team to complete such tasks as chart work at sea, and maintenance and ship management in port, by daylight or darkness.

7.5.5 A satisfactory level of flexibility within the lighting system is to be available to enable members of the bridge team to adjust the lighting in brightness and direction as required in different areas of the bridge and by individual user interface devices.

7.5.6 During hours of darkness it is to be possible for bridge personnel to discern equipment on the bridge so that they can move about and locate equipment.

7.5.7 Red or low intensity light is to be used to maintain dark adaptation whenever possible in areas or on items of equipment, other than the chart table, requiring illumination in the operational mode. This is to include equipment in the bridge wings.

7.5.8 Indirect low level red or low intensity lighting is to be available at deck level, especially for internal doors and staircases. Provision is to be made to prevent red lights from being seen from outside the ship.

7.5.9 Instrument lighting in specified areas is to be such that duty personnel can read off dials and indicators without impediment of night vision.

7.5.10 Lighting of instruments, keyboards and controls are to be adjustable down to zero, except for the lighting of alarm and warning indicators and the controls of dimmers which are to remain readable.

■ *Section 1* General requirements

1.1 General

1.1.1 This Chapter states the requirements for made and fresh water systems installed in naval ships.

1.1.2 The requirements in this Chapter cover arrangements, equipment, piping and control systems necessary for the production and distribution of made and fresh water systems for domestic and other systems requiring defined quality and quantity capabilities.

1.2 Scope

1.2.1 Made and fresh water systems included in this Chapter are for:

(a) Use of crew and embarked personnel for domestic services and food preparation.
(b) Use in cooling water systems.
(c) Use in chilled water systems, *see Vol 2, Pt 7, Ch 5 Ship Type Piping Systems*.
(d) Use in boiler feed systems.
(e) Use for bridge window washing arrangements.

1.2.2 Where the Owner requires the capability of the made and fresh water systems for purposes other than those listed in *Vol 2, Pt 11, Ch 1, 1.2 Scope 1.2.1* (e.g. engine and aircraft washing), the Owner is responsible for defining the requirements for quality and quantity capabilities.

1.3 Documentation required for design review

1.3.1 In addition to the information required by *Vol 2, Pt 7, Ch 1, 2.1 Documentation required for design review 2.1.1*, three copies of the plans and information stated in *Vol 2, Pt 11, Ch 1, 1.3 Documentation required for design review 1.3.3* to *Vol 2, Pt 11, Ch 1, 1.3 Documentation required for design review 1.3.8* are to be submitted to Lloyd's Register (hereinafter referred to as 'LR') as applicable.

1.3.2 **System Design Description**. A System Design Description of the made and fresh water system. *See Vol 2, Pt 1, Ch 3, 3.5 System design description* and *Vol 2, Pt 11, Ch 1, 3.1 Water storage facilities 3.1.1*, *Vol 2, Pt 11, Ch 1, 3.2 Made water production facilities 3.2.2*, *Vol 2, Pt 11, Ch 1, 3.2 Made water production facilities 3.2.3*, *Vol 2, Pt 11, Ch 1, 3.3 Piping system design 3.3.2*, *Vol 2, Pt 11, Ch 1, 3.4 Piping system distribution 3.4.2*, *Vol 2, Pt 11, Ch 1, 3.4 Piping system distribution 3.4.6* and *Vol 2, Pt 11, Ch 1, 5.3 Trials 5.3.1* for specific references to the System Design Description .

1.3.3 **Systems**. Plans in diagrammatic form showing piping arrangements, control systems and safeguards and electrical systems covered by this Chapter. The major component parts, pipe sizes, system flow rates and pressures together with the capacities of pumps and plants for making water are to be included in the plans.

1.3.4 **Compartments**. Plans showing the general arrangement of compartments, together with a description of the arrangements installed for making, storage and distribution of water and the electrical power supply systems. The plans are to indicate segregation and access arrangements for compartments and associated control rooms/stations.

1.3.5 **Testing and trials procedures**. A schedule of testing and trials to demonstrate that systems are capable of operating as described in *Vol 2, Pt 11, Ch 1, 3 System arrangements* and as required by *Vol 2, Pt 11, Ch 1, 5 Testing and trials*.

1.3.6 **Operating manuals**. Operating manuals are to be provided on board and submitted for information where requested by LR. The manuals are to include the following information:

(a) Particulars and a description of the systems for the production, storage and distribution of made and fresh water. The particulars are to include system arrangement plans showing each mode of operation of each system.
(b) Operating arrangements for each mode of operation for the equipment and systems installed.
(c) Cleaning arrangements and any precautions required for the use, storage and disposal of any recommended chemicals used for cleaning systems and equipment.
(d) Coating and maintenance instructions for water storage tanks.
(e) Cleaning instructions for filters, calorifiers and other equipment where bacteria may accumulate in fresh water systems for use of crew and embarked personnel and for food preparation.
(f) Maintenance instructions and fault finding procedures for the equipment and systems.

1.3.7 **Certificates**. Coating specification with certificate of testing for toxicity and tainting testing by an independent test laboratory.

1.3.8 **Specification**. Specification of metallic and nonmetallic materials in contact with made and fresh water.

■ *Section 2* System construction and installation

2.1 Materials

2.1.1 Pipes, valves and fittings are, in general, to be made of steel, ductile cast iron, copper, copper alloy, or other approved ductile material suitable for the intended purpose. The use of plastics materials is also acceptable subject to any restrictions in *Vol 2, Pt 7, Ch 1 Piping Design Requirements*.

2.1.2 Where applicable, the materials are to comply with the requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements*.

2.1.3 The selection of materials in piping systems is to recognise the following details:

(a) Fluid properties, pressures and temperatures.
(b) Location and configuration.
(c) Compatibility of materials.
(d) Fluid flow rates and static conditions.
(e) Minimising corrosion and erosion through life of system.
(f) System survey, cleaning and maintenance requirements.

See Vol 2, Pt 7, Ch 1, 17 Guidance notes on metal pipes for water service for guidance notes on metal pipes for water services.

2.1.4 Materials for use in fresh water systems for use of crew and embarked personnel and for food preparation are to be of types that do not provide a habitat for bacteria which can occur with natural rubber, various plastics and fibre accessories, and do not leach out toxic constituents.

2.2 Pipe wall thickness

2.2.1 The minimum nominal wall thickness of steel, copper and copper alloy pipes are to be in accordance with *Vol 2, Pt 7, Ch 1 Piping Design Requirements*.

2.2.2 Special consideration will be given to the wall thickness of pipes made of materials other than steel, copper and copper alloy.

2.3 Piping and equipment - Selection and installation

2.3.1 Pressurised tanks are to be in accordance with the requirements of *Vol 2, Pt 8, Ch 2 Other Pressure Vessels*.

2.3.2 Valves, flexible hose lengths, expansion pieces and pumps are to comply with the relevant requirements of *Vol 2, Pt 7, Ch 1, 12 Valves* to *Vol 2, Pt 7, Ch 1, 15 Pumps*, (*see also Vol 2, Pt 11, Ch 1, 2.1 Materials* regarding selection of materials). The configuration of piping systems is to be arranged to minimise erosion and corrosion of pipe and equipment materials. Equipment used in made and fresh water systems and piping systems is to be suitable for its intended purpose, and accordingly, wherever practicable, be selected from the Lists of LR Type Approved Products published by LR.

2.3.3 Pipes in piping systems are to be permanent pipes made with approved pipe connections to enable ready removal of valves, pumps, fittings and equipment. The pipes are to be efficiently secured in position to prevent chafing or lateral movement.

2.3.4 Suitable means for expansion is to be made, where necessary, in each range of pipes.

2.3.5 Efficient protection is to be provided for all pipes situated where they are liable to mechanical damage.

2.3.6 All moving parts are to be provided with guards to minimise danger to personnel.

2.4 Valves - Installation and control

2.4.1 Valves are to be fitted in places where they are at all times readily accessible.

2.4.2 All valves that are provided with remote control arrangements are to be arranged for local manual operation, independent of the remote operating mechanism. The local manual means of operation is to be readily accessible.

2.4.3 Relief valves are to be adjusted and bursting disks so selected that they relieve at a pressure not greater than the design pressure of the system. When satisfactorily adjusted, relief valves are to be protected against tampering or interference by wire with a lead seal or similar arrangement.

2.5 Cathodic protection

2.5.1 Sacrificial anode cathodic protection is not permitted in made and fresh water storage tanks.

2.6 Coating of storage tanks and piping internal surfaces

2.6.1 Storage tanks, piping and valves constructed from carbon and low alloy steels and cast irons are to be lined internally with a corrosion control coating suitable for the containment and transfer of made and fresh water.

2.6.2 Corrosion control coatings are to be tested and certified as complying with standards specified by the Designer and Owner.

2.7 Plastics piping and flexible hoses

2.7.1 Subject to compliance with *Vol 2, Pt 7, Ch 1, 11 Pipe connections* and *Vol 2, Pt 7, Ch 1, 13 Flexible hoses*, and the relevant Sections of *Vol 2, Pt 7, Ch 2 Ship Piping System*, plastics piping which is internally uncoated may be used in piping systems for made and fresh water.

2.7.2 Any internally uncoated plastics piping or flexible hose in contact with made or fresh water is to be suitable for the containment and transfer of made and fresh water.

2.7.3 Uncoated plastics piping and flexible hoses are to be tested and certified as complying with current standards for use in made and fresh water systems.

2.7.4 Plastics piping is to be selected in consultation with the manufacturers with regard to suitability with the proposed pipe system cleaning practice.

■ *Section 3*
System arrangements

3.1 Water storage facilities

3.1.1 Sufficient potable water storage is to be provided to cater for the needs of the full ship's complement and embarked personnel recognising the operating role of the ship that is to be declared in the System Design Description required by *Vol 2, Pt 11, Ch 1, 1.3 Documentation required for design review 1.3.2*. For example, a ship may be expected to spend some time in littoral waters where production of fresh water using installed plant may not be possible due to plant limitations or statutory regulations.

The combination of storage, water production rate and usage is to be carefully considered in the vessel design, taking into account both average and peak loadings, the latter of which may be typically three times the normal usage rate.

3.1.2 At least two storage tanks are to be fitted, each with separate means of supplying the fresh water distribution main. The tanks are to be spacially separated and in NS1 and NS2 type ships at least one of the tanks is to be sited other than in the double bottom space. The tanks are to sited and be of such dimensions that they are readily accessible to facilitate inspection, cleaning and coating.

3.1.3 The internal structure of fresh water tanks is to be designed to ensure efficient drainage to the suction point. Fresh water tanks are not to have a common boundary with another tank that can contain oil or any other liquid except fresh water ballast. Access arrangements to storage tanks are to be arranged and sited clear of sources of possible contamination.

3.1.4 Pipes other than piping containing fresh water of the same quality as the tank contents are not to pass through or be located within a fresh water tank. Pipes carrying fresh water are not to pass through tanks other than fresh water tanks.

3.1.5 The storage facilities for made water intended for boiler feed services are to be independent of potable water systems for crew and embarked personnel. The storage and piping arrangements are to comply with *Vol 2, Pt 7, Ch 3, 6 Boiler feed water, condensate and thermal fluid circulation systems*.

3.1.6 Water storage tanks are to be provided with means of indicating the water level. The means of routine level inspection is to be by means other than by the use of sounding rods.

3.1.7 Air, filling and sounding arrangements for fresh water storage tanks are to located and arranged to prevent an ingress of a contaminant. The arrangements for filling are to include a deck connection to facilitate external loading.

3.1.8 Where specified, separate storage tank(s) in addition to the two storage tanks required by *Vol 2, Pt 11, Ch 1, 3.1 Water storage facilities 3.1.2* is/are to be provided. The tank(s) is/are to be provided with means for treatment of water in the tank for decontamination or other purposes that may be specified by the Owner.

3.2 Made water production facilities

3.2.1 Made water production facilities fitted are to be capable of producing water to World Health Organisation *Guidelines for Drinking Water Quality, Volume 1 Recommendations Second Edition 1994* as a minimum requirement. A more stringent quality of water production may be necessary in the case of water for use in, for example, boiler feed systems. In these cases, an alternative means of water production is to be provided or a further stage of desalination included in the production arrangements. Where the specified standards for made water are other than the World Health Organisation Standards, these are to be provided to LR.

3.2.2 The total capacity of the fresh water generation plant will depend upon a number of parameters including complement, ship operating profile and other equipment supplied, but typically will be of the order of 135 litres/man/day plus 450 litres/aircraft/day. The capacity of the plant and tank storage is to be specified by the Owner and declared in the System Design Description required by *Vol 2, Pt 11, Ch 1, 1.3 Documentation required for design review 1.3.2*.

3.2.3 Two or more plants for making water are to be provided, of sufficient combined capacity to produce sufficient water under defined levels of requirements stated in the System Design Description required by *Vol 2, Pt 11, Ch 1, 1.3 Documentation required for design review 1.3.2*. Provision of single plant will be considered in conjunction with the operational requirements of the ship and any assigned service restriction.

3.2.4 The design of plants for making water is to be such that permits cleaning, maintenance and repair of any plant whilst the other is in service.

3.2.5 Adequate cleaning arrangements are to be fitted to water generating plants. A suitable safe area is to be designated for system cleaning agents.

3.2.6 In the case of distilling type plants, adequate safeguards are to be incorporated to prevent excess steam pressure. Steam piping arrangements are to comply with *Vol 2, Pt 7, Ch 3, 5 Steam piping systems*.

3.2.7 Where there are low-pressure evaporators using diesel engine jacket water as the heating medium, any corrosion inhibitors in the jacket water are specifically approved for that application.

3.2.8 Means are to be provided to automatically enable produced water that falls below specification to be prevented from being discharged into the supply for distribution into the fresh and made water storage and user systems. The arrangements are to minimise the risk of contamination of made water storage facilities if the made water quality from the plant falls below specification.

3.3 Piping system design

3.3.1 Piping system arrangements are to be such that the supply of made and fresh water can be made to Mobility and/or Ship Type systems such as chilled water, machinery fresh water cooling and boiler feed water in the event of a single failure or damage of a system or item of equipment. As far as possible, permanent connections to these systems are to be avoided to prevent contamination of the fresh water by additives such as corrosion inhibitors that may be present in the systems. Where it is essential to fit permanent connections, means are to be provided to isolate the systems from the fresh water supplies to ensure that cross contamination cannot take place when the systems are operating normally.

3.3.2 The design of piping systems is to recognise operational and manning philosophy for the vessel and is to be declared in the System Design Description required by *Vol 2, Pt 11, Ch 1, 1.3 Documentation required for design review 1.3.2*.

3.3.3 Where a piping system has failed or been damaged, any resulting hazards are to be capable of being minimised.

3.3.4 All equipment fitted in piping systems is to be readily accessible to facilitate maintenance and survey. For this purpose, valves or cocks are to be interposed between items of equipment and the inlet and outlet pipes in order that any item of equipment may be shut off for opening up and overhauling.

3.3.5 Any filter elements fitted in equipment or piping systems are to be capable of being cleaned and/or changed.

3.3.6 Pressure relief devices are to be mounted in such a way that it is not possible to isolate them from the part of the system which they are protecting except that, where duplicated, a changeover valve may be fitted that will allow either device to be isolated for maintenance purposes without it being possible to shut off the other device at the same time.

3.3.7 Seawater valves and fittings are to comply with *Vol 2, Pt 7, Ch 2, 2.5 Ship-side valves and fittings (other than those on scuppers and sanitary discharges)*.

3.3.8 Not less than two sea inlets are to be provided for pumps supplying seawater to the fresh water generating plants. The sea inlets are to be independent of other sea inlets and are to be located forward and clear of any bilge or sanitary discharges.

3.3.9 Where a high pressure sea water system is installed (*see Vol 2, Pt 7, Ch 5 Ship Type Piping Systems*), provision is to be made for emergency supply to the made water plant.

3.3.10 Provision is to be made for all seawater to pass through suitable filters before being introduced to the made water plant. The filters are to be in accordance with the equipment manufacturer's recommendations.

3.3.11 Piping system arrangements and associated equipment are to be capable of operating satisfactorily under the conditions shown in *Table 3.4.2 Inclinations* in *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*.

3.3.12 The system is to be capable of being cleaned with arrangements for safely flushing out any cleaning chemical agents after use and for storing or disposing of them safely.

3.4 Piping system distribution

3.4.1 Two or more water pumps are to be provided of sufficient capacity to supply the water distribution system with any one pump out of action.

3.4.2 The water distribution system is to be capable of providing a steady flow of water at any point in the system in accordance with the System Design Description required by *Vol 2, Pt 11, Ch 1, 1.3 Documentation required for design review 1.3.2*. Where a pneumatically pressurised tank arrangement is used, the tank is to be provided with water level indication and a means of indicating the pressure. The compressed air connection to the pressurised tank is to incorporate a non-return valve arrangement at the tank to prevent the possibility of water entering the compressed air system and it is recommended that the connection be made via a portable hose connection.

3.4.3 Each user or group of users of fresh water are to be provided with means of isolation such that the distribution system can continue to function when a user or group of users has been isolated.

3.4.4 Air vent and drain points are to be provided throughout the system at all high and low points.

3.4.5 Provision is to be made for filling the water storage system(s) from the made water production facilities. Shore connection located above the waterline and an associated dry main are to be provided to permit the filling of the storage system.

3.4.6 Provision is to be made to connect an alternative source of water supply to defined services in emergency/ action damage conditions. For example, where the fresh water main is unavailable, stand-by arrangements are to be provided for suitable water supplies to medical spaces, galleys, bridge window sprays, cleansing stations (CBRN Protection fitted vessels) and weapon

cooling. The supply arrangements to defined services in emergency/action damage conditions are to be included in the System Design Description required by *Vol 2, Pt 11, Ch 1, 1.3 Documentation required for design review 1.3.2* and agreed by the Owner.

3.4.7 There are to be no permanent connections between fresh water and sea water systems. Where emergency connections have been designed for the supply of fresh water to fresh and seawater cooled equipment, the fresh water is to be supplied by means of a portable hose with screw down non-return valve isolation arrangements at the connection to the equipment.

3.4.8 The temperature of domestic hot water systems is to be maintained above 63°C except in cases of peak demand when a fall to no less than 60° is acceptable. The distribution system is to be provided with a means of continuous circulation to resist bacteriological contamination of the system.

3.4.9 Calorifiers are to be provided with drainage arrangements and adequate access to enable cleaning.

3.4.10 Provision is to be made for all water supplies intended for domestic services and food preparation to be sterilised by chlorination that maintains residual free chlorine content of 0,2 ppm or by an equivalent sterilisation method. Means are also to be provided to chlorinate all fresh water taken from shore, water barge or supply ship on loading to a sufficient concentration to ensure a residual free chlorine content of 0,2 ppm.

3.4.11 The water supply arrangements intended for crew and embarked personnel for drinking, washing or food preparation is to be independent of other services wherever possible. Where there are no alternative supply arrangements to other services requiring fresh water (e.g. machinery cooling water, purifiers or a fresh water WC flushing system), a clear air break is to be provided in the fresh water supply pipe to such a system or tank. If it is impracticable to provide a clear air break, the supply pipe to each system is to be provided with an efficient non-return valve and a vacuum breaker or back-flow preventer.

■ *Section 4*
Control and monitoring and electrical power arrangements

4.1 General

4.1.1 The control engineering arrangements are to comply with *Vol 2, Pt 9, Ch 1 General Requirements for the Design and Construction of Electrotechnical Systems* & *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems* as applicable.

4.1.2 Equipment used in made and fresh water systems is to be provided with local control and monitoring arrangements.

4.1.3 Where isolation of equipment or systems can be carried out, means of indicating the status of isolation is to be provided at positions where the equipment and system can be operated and monitored.

4.1.4 Instrumentation to indicate the operational status of running and any standby equipment is to be provided locally and at each control station.

4.1.5 All pumps are to be provided with an indication of discharge pressure and a low discharge pressure alarm at the control station.

4.1.6 Made water plant instrumentation is to include, as a minimum, salinity indication and high salinity alarm of the made water at the plant and at each control station.

4.1.7 Arrangements are to be made to automatically divert any made water that is above the specified salinity limit from distribution into the made water storage system.

4.1.8 Made water systems using reverse osmosis plant are to be provided with automatic means of chlorinating the made water downstream of the plant.

4.1.9 Calorifiers are to be provided with a means of indicating and controlling the outlet temperature of fresh water to distribution systems. Low and high temperature alarms are to be provided in the hot water distribution system at each control station.

4.1.10 The electrical engineering arrangements are to comply with *Vol 2, Pt 9 Electrotechnical Systems*.

Section 5
Testing and trials

5.1 Testing

5.1.1 The requirements of the Rules relating to testing of pressure vessels, piping and related fittings including hydraulic testing are applicable. *See Vol 2, Pt 8, Ch 2, 10 Hydraulic tests* and *Vol 2, Pt 7, Ch 1, 16 Testing*.

5.1.2 On completion, tanks and reservoirs for service and storage of system fluids are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

5.1.3 After installation on board, piping systems together with associated fittings that are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

5.1.4 Testing is to cover the following items.

(a) Verification of control, alarm, safety systems.
(b) Tests simulating failure of made water production equipment and pumps to verify correct functioning of alarms and systems in service.
(c) Verification of accuracy, calibration and functioning of temperature control for hot water heating, monitoring and recording instrumentation for produced water systems where fitted.

5.2 Type testing

5.2.1 Evidence that the required performance of made water and pumping equipment is capable of being maintained under ambient and inclination operating conditions defined in *Vol 2, Pt 1, Ch 3, 4.4 Ambient reference conditions* and *Vol 2, Pt 1, Ch 3, 4.6 Inclination of ship* is to be provided by the manufacturer.

5.3 Trials

5.3.1 Trials are to be carried out to demonstrate that the capability of the production, storage and distribution systems for made and fresh water systems meet the System Design Description. The trials are as far practicable to be representative of the actual conditions to be encountered in service.

Section

■ *Section 1* General requirements

1.1 General

1.1.1 This Chapter states the requirements for heating, ventilation and cooling arrangements (HVAC) systems installed in naval ships.

1.1.2 The requirements in this Chapter cover arrangements, equipment, and control systems necessary for effective heating, ventilation and cooling arrangements on board a naval ship.

1.2 Scope

1.2.1 HVAC systems included in this Chapter cover the following as applicable.

(a) Crew and embarked personnel spaces.
(b) Magazines and stores and spaces containing flammable liquids and gases.
(c) Storerooms, workshops, sewage handling spaces.
(d) Galleys
(e) Medical spaces
(f) Welldecks

1.2.2 This Chapter also includes requirements for smoke clearance.

1.2.3 Machinery space ventilation systems are to comply with *Vol 2, Pt 1, Ch 3, 5.7 Ventilation*.

1.2.4 Pump room ventilation systems are to comply with *Vol 2, Pt 7, Ch 4, 3 Pump rooms* as applicable.

1.2.5 Vehicle, helicopter and aircraft space ventilation arrangements are to comply with *Vol 2, Pt 9, Ch 5, 4.10 Requirements for oil supply ships intended for the carriage in bulk of oil cargoes having a flash point not exceeding 60°C (closed-cup test)* as applicable.

1.2.6 CBRN Protection guidance for ventilation is contained in *Vol 2, Pt 1, Ch 3, 4.12 Guidance for CBRN protection, detection and monitoring*.

1.2.7 The requirements of *Vol 2, Pt 7, Ch 5 Ship Type Piping Systems* are also applicable where a chilled water system is used for cooling purposes.

1.2.8 Battery room ventilation arrangements are to comply with *Vol 2, Pt 9, Ch 2, 7.5 Ventilation*.

1.3 Documentation required for design review

1.3.1 Three copies of the plans and information stated in *Vol 2, Pt 11, Ch 2, 1.3 Documentation required for design review 1.3.2* to *Vol 2, Pt 11, Ch 2, 1.3 Documentation required for design review 1.3.6* are to be submitted to Lloyd's Register (hereinafter referred to as 'LR') as applicable.

1.3.2 **System Design Description**. A System Design Description of the HVAC systems. *See Vol 2, Pt 1, Ch 3, 3.5 System design description* and *Vol 2, Pt 11, Ch 2, 2.4 Refrigerant systems for cooling 2.4.1*, *Vol 2, Pt 11, Ch 2, 2.5 Heating plant 2.5.1*, *Vol 2, Pt 11, Ch 2, 2.6 Filtration units for air intakes 2.6.1*, *Vol 2, Pt 11, Ch 2, 3.1 General 3.1.2*, *Vol 2, Pt 11, Ch 2, 3.1 General*

3.1.4, *Vol 2, Pt 11, Ch 2, 3.3 Galleys 3.3.1*, *Vol 2, Pt 11, Ch 2, 3.6 Smoke clearance 3.6.1* and *Vol 2, Pt 11, Ch 2, 5.3 Trials 5.3.1* for specific references to the System Design Description.

1.3.3 **Systems**. Plans in diagrammatic form showing air intake/exhaust/distribution arrangements, control systems and safeguards and electrical systems covered by this Chapter. Plans are to show trunk/pipe sizes, air/water flows and terminal locations. The capacities of fans, pumps and heating/cooling/filtration plants are to be included. Capacity tables for different operating conditions for the refrigeration compressors are also to be included.

1.3.4 **Compartments**. Plans showing the general arrangement of compartments, together with a description of the equipment and arrangements installed for isolation, heating/ cooling/filtration and distribution of ventilation air and the electrical power supply systems. The plans are to indicate segregation and access arrangements for compartments and associated control rooms/stations.

1.3.5 **Testing and trials procedures**. A schedule of testing and trials to demonstrate that systems are capable of operating as described in *Vol 2, Pt 11, Ch 2, 3 System arrangements*.

1.3.6 **Operating manuals**. Operating manuals are to be provided on board and submitted for information where requested by LR. The manuals are to include the following information:

(a) Particulars and a description of the systems.
(b) Operating instructions for the equipment and systems (including fire isolation aspects).
(c) Maintenance instructions for the installed arrangements.

■ *Section 2* Construction and installation

2.1 Materials

2.1.1 The selection of materials in piping systems for heating, cooling and filtration systems is to recognise the following details:

(a) Fluids, pressures and temperatures.
(b) Location.
(c) Compatibility of materials.
(d) Fluid flow rates and static conditions.
(e) Minimising corrosion and erosion through life of system.
(f) Flammability and toxicity.

2.1.2 Ventilation trunk materials and characteristics are to be selected to suit the application. For example, watertight or gastight trunking may be required in certain areas of the vessel in order to meet the design requirements. Steel trunking is to be used in areas of high fire risk.

2.1.3 Where trunking is fitted in lengths and required to be joined together, joining arrangements are to be in accordance with the requirements of the trunk manufacturer.

2.1.4 Pipes, valves and fittings are in general to be made of steel, ductile cast iron, copper, copper alloy, or other approved ductile material suitable for the intended purpose. The use of plastics materials is also acceptable subject to the restrictions in *Vol 2, Pt 7, Ch 1 Piping Design Requirements*.

2.1.5 Where applicable, the materials are to comply with the requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements*.

2.2 Equipment - Selection and installation

2.2.1 Pressure vessels in heat exchange systems are to be in accordance with *Vol 2, Pt 8, Ch 2 Other Pressure Vessels* or a recognised code.

2.2.2 Valves, flexible hose lengths, expansion pieces and pumps are to comply with the relevant requirements of *Vol 2, Pt 7, Ch 1, 12 Valves*.

2.2.3 Pipes in piping systems are to be permanent pipes made with approved pipe connections to enable ready removal of valves, pumps, fittings and equipment. The pipes are to be efficiently secured in position to prevent chafing or lateral movement.

2.2.4 Suitable means for expansion is to be made, where necessary, in each range of pipes.

2.2.5 Efficient protection is to be provided for all pipes situated where they are liable to mechanical damage.

2.2.6 All moving parts are to be provided with guards to minimise danger to personnel.

2.2.7 Low temperature pipes in refrigeration systems are to be provided with efficient insulation. Chilled water and hot water pipes are also to be provided with insulation for system efficiency.

2.2.8 Means are to be provided, where necessary, to enable lengths of ventilation trunking to be cleaned internally.

2.3 Valves and isolation flaps - Installation and control

2.3.1 Valves and isolation flap arrangements are to be fitted in places where they are at all times readily accessible.

2.3.2 All valves that are provided with remote control arrangements are to be arranged for local manual operation, independent of the remote operating mechanism. The local manual means of operation is to be readily accessible.

2.3.3 Relief valves are to be adjusted and bursting discs so selected that they relieve at a pressure not greater than the design pressure of the system. When satisfactorily adjusted, relief valves are to be protected against tampering or interference by wire with a lead seal or similar arrangement.

2.4 Refrigerant systems for cooling

2.4.1 Where chilled water systems complying with *Vol 2, Pt 7, Ch 5 Ship Type Piping Systems* are not used for cooling ventilation air, independent refrigeration plants are to be provided and designed to be capable of extracting a defined heat load duty when operating at the conditions stated in the System Design Description required by *Vol 2, Pt 11, Ch 2, 1.3 Documentation required for design review 1.3.2*. Independent refrigeration plants are to comply with the requirements of this Chapter.

2.4.2 The compartments containing the refrigeration plants are to be provided with refrigerant gas detectors with audible and visual alarms.

2.4.3 The design of refrigeration systems is to be such that permits maintenance and repair without unavoidable loss of refrigerant to atmosphere. To minimise refrigerant release to the atmosphere, refrigerant recovery units are to be provided for evacuation of a system prior to maintenance.

2.4.4 Refrigeration systems are to be provided with relief devices, but it is important to avoid circumstances that would bring about an inadvertent discharge of refrigerant to the atmosphere. The system is to be so designed that pressure due to fire conditions will be safely relieved.

2.4.5 A pressure relief valve and/or bursting disc is to be fitted between each positive displacement compressor and its gas delivery stop valve, the discharge being led to the suction side of the compressor. The flow capacity of the valve or disc is to exceed the full load compressor capacity on the particular refrigerant at the maximum potential suction pressure. For these internal relief valves, servo-operated valves will be accepted. Where the motive power for the compressor does not exceed 10 kW, the pressure relief valve and/or bursting disc may be omitted.

2.4.6 Each pressure vessel which may contain liquid refrigerant and which is capable of being isolated by means of a stop or automatic control or check valves is to be protected by two pressure relief valves or two bursting discs, or one of each, controlled by a changeover device. Pressure vessels that are connected by pipework without valves, so that they cannot be isolated from each other, may be regarded as a single pressure vessel for this purpose, provided that the interconnecting pipework does not prevent effective venting of any pressure vessel.

2.4.7 Omission of one of the specified relief devices and changeover device, as required by *Vol 2, Pt 11, Ch 2, 2.4 Refrigerant systems for cooling 2.4.6*, will be accepted where:

(a) Vessels are of less than 300 litres internal gross volume;

or

(a) Vessels discharge into the low pressure side by means of a relief valve.

2.4.8 Sections of systems and components that could become full of liquid between closed valves are to be provided with pressure relief devices relieving to a suitable point in the refrigerant circuit.

2.4.9 Seawater systems for refrigeration condensers are to be capable of being supplied from not less than two independent sources. If required by the System Design Description, these sources are to be located in separate compartments and zones such that the loss of one zone or compartment will not result in the loss of all seawater supply sources.

2.4.10 The capacity of each source of seawater required by *Vol 2, Pt 11, Ch 2, 2.4 Refrigerant systems for cooling 2.4.9* is to be sufficient for the conditions stated in the System Design Description with any one source out of action.

2.5 Heating plant

2.5.1 Independent means of heating the air supplies to ventilation systems for crew and embarked personnel are to be designed to be capable of transferring a defined heat load duty when operating at the conditions stated in the System Design Description required by *Vol 2, Pt 11, Ch 2, 1.3 Documentation required for design review 1.3.2*.

2.6 Filtration units for air intakes

2.6.1 Air inlets and outlets to all ventilation systems are to be provided with suitable protection screens. Filtration units are to be provided at all inlets to air supplies to ventilation systems for crew and embarked personnel in accordance with the conditions stated in the System Design Description.

2.6.2 Air filtration units are to be provided to control the ingestion of water, particulate and corrosive marine salts and are to be capable of being cleaned in accordance with the manufacturer's recommendations.

2.6.3 Filtration units for CBRN Protection are to be in accordance with the guidance in *Vol 2, Pt 1, Ch 3, 4.12 Guidance for CBRN protection, detection and monitoring* as applicable.

■ *Section 3* System arrangements

3.1 General

3.1.1 The design of air-conditioning and ventilation systems is to reflect the total ship design including any requirements of the System Design Description, specified subdivision and stability standard, fire safety standard or other particular features stipulated in the standards specified for the ship.

3.1.2 The design and capability of supply and exhaust systems for ventilation purposes are to address the following requirements as applicable:

(a) Noxious odours, toxic and dangerous fumes or other contaminants are to be extracted, taking into account any requirements of the CBRN System Design Description.

(b) Acceptable levels of fresh air are to be provided for personnel efficiency, combustion or other oxidation processes. The arrangements are to ensure that maximum CO_2 levels are not exceeded in all spaces where crew and embarked personnel are likely to be.

  (i) a maximum CO_2 level of 1200 ppm is to be adopted. A high level alarm is to be provided where 100 per cent recirculation is adopted for any ship operational requirement.

  (ii) a minimum fresh air flow of 5 litres/s/man is to be capable of being supplied to all spaces intended for crew and embarked personnel.

(c) In a fire situation within an autonomous zone, smoke migration is to be restricted to prevent ingress into compartments essential for the operational capability of the ship in a fire situation.

(d) Acceptable internal ambient conditions are to be maintained for personnel comfort in manned compartments and in other compartments where required for equipment cooling. The arrangements for maintaining acceptable ambient conditions are to take account of the range of climatic conditions that the ship is required to operate within and are to be included in the System Design Description required by *Vol 2, Pt 11, Ch 2, 1.3 Documentation required for design review 1.3.2*.

(e) Systems are to be arranged so that as far as is practicable they serve like compartments from the same sub-systems.

(f) If the vessel is divided into autonomous zones, the systems are to be designed so that they do not cross over from one zone boundary to another.

(g) In the case of vessels designed for CBRN Protection, the system is to be designed to maintain the vessel at an overpressure relative to the outside ambient pressure. The system is also to provide a breathable atmosphere, minimising CO_2 levels with the maximum ship's complement. Odour filtration is to be provided for all those areas that are likely to produce foul smells and are subject to recirculation in closedown, e.g. bathrooms, toilets, galleys. *See Vol 2, Pt 1, Ch 3, 4.12 Guidance for CBRN protection, detection and monitoring* for CBRN Protection guidance.

(h) The systems are to be designed to maintain the vessel's watertight integrity and, for ships with CBRN Protection arrangements, gastight integrity.

(i) Systems are to be designed to enable inspection, cleaning and maintenance in accordance with the designer's and equipment manufacturer's recommendations.

3.1.3 Exhausts from clean workshops may be returned to the ship's recirculation system via suitable filter arrangements. However, the air conditioning system is not to be used for dust extraction from woodworking machinery, etc. Independent extraction systems are to be used for this purpose. Similarly, fumes from welding bays, etc. are to be exhausted to atmosphere.

3.1.4 Exhausts from sewage treatment spaces are normally to be led to atmosphere. Where identified in the System Design Description, exhausts may be led to the ship's recirculation system but means of isolation to the recirculation system with alternative exhaust to atmosphere arrangements are to be provided to cater for abnormal plant conditions.

3.1.5 Exhausts from storerooms containing non-hazardous materials may be returned to the ship's recirculation system.

3.1.6 Exhaust arrangements from machinery spaces, pump room, aircraft and vehicle decks are to be led to atmosphere.

3.1.7 All openings in weatherdeck boundaries are to be fitted with grilles to avoid ingress of debris. Consideration is to be given to weatherdeck openings to prevent downflooding.

3.1.8 Facilities are to be provided to ensure that weatherdeck openings remain clear of ice when the ship is operating in the coldest climate for which it is designed.

3.1.9 In compartments or spaces with low noise targets or in operational spaces, accommodation, working or office areas, the design of the distribution system is to be such as to minimise noise generation.

3.2 Magazines, stores and spaces containing flammable liquids and gases/vapours

3.2.1 The design of ventilation arrangements to magazines is to minimise the risk of explosion. Where fitted, exhausts from magazines are to be led to atmosphere.

3.2.2 Systems serving compartments containing flammable stores (e.g. paint stores) or potentially explosive gases (including battery charging rooms, oxygen bottle stores and magazines) are to be fitted with flameproof gauzes and isolating valves in these branches. The systems serving such compartments are to be independent of those supplying other spaces. Fans supplying and extracting air to/from such compartments are to be spark resistant as a minimum, *see Vol 2, Pt 7, Ch 4, 3.3 Non-sparking fans for hazardous areas*. Exhausts are to be led to atmosphere away from other outlets, i.e. fuel tank vents.

3.2.3 Exhausts from compartments containing hazardous materials, including dangerous or noxious gases (e.g. refrigeration machinery), are to be led to atmosphere.

3.2.4 Electrical equipment (including any heating arrangements) for magazines, stores and spaces containing flammable gases and vapours is to comply with *Vol 2, Pt 9, Ch 5 Hazardous Areas*.

3.3 Galleys

3.3.1 The following arrangements are to be incorporated in ventilation systems within galleys:

(a) All trunking is to be of steel or stainless steel.

(b) Exhaust terminals above equipment such as fryers, grills, etc, are to be fitted with grease filters that can easily be removed and cleaned.

(c) Exhaust branches, fitted with grease filters, are to be protected by fire flaps within the galley. The flaps are to be sited in the exhaust trunking between the canopy and the exit from the galley, arranged to close in the direction of air flow and be readily operable from both within and outside the galley.

(d) CO_2 injection or other fire extinguishing means facilities are to be fitted.

Exhaust systems from galleys are normally to be led to atmosphere. In the case of ships fitted with CBRN Protection and when identified in the System Design Description, the galley ventilation system may be designed to recirculate air and, to limit food smells, odour filtration is to be provided. If the exhaust is led to atmosphere in ships fitted with CBRN Protection, the air loss is to be considered when assessing the CBRN arrangements.

3.3.2 In addition to those fitted in galley systems, fire flaps are also to be fitted:

(a) In ventilation trunks that pass through designated fire barriers.

(b) In ventilation trunks that pass through watertight bulkheads where this penetration occurs within the lines of weathertight and watertight integrity as defined in *Vol 1, Pt 3, Ch 2 Ship design*.

3.4 Medical spaces

3.4.1 Sick bay complexes are to be provided with a dedicated air treatment unit with trunked distribution, fresh air, recirculation and where necessary, exhaust systems.

3.4.2 The arrangements for ventilation of medical compartments are to be such that they are capable of maintaining a positive pressure in relation to the surrounding complex to prevent the ingress of any contaminated air. Similarly, any operating theatres are to have arrangements for providing a relative positive pressure to the adjacent medical spaces.

3.5 Welldecks

3.5.1 Welldeck spaces are to be designed with ventilation systems that provide a safe working environment for a defined period of time which in general should be not less than 8 hours.

3.5.2 Guidance for the design of ventilation systems for welldeck spaces can be found in IMO MSC/Circular 729 – *Design Guidelines and Operational Recommendations for Ventilation Systems in Ro-Ro Cargo Spaces*.

3.6 Smoke clearance

3.6.1 In addition to the requirements in *Vol 2, Pt 11, Ch 2, 3.1 General*, where the Owner has specified the installation of a smoke clearance system. The design of such a system is to be based on the declared operating philosophy identified in the System Design Description required by *Vol 2, Pt 11, Ch 2, 1.3 Documentation required for design review 1.3.2* which, in general, should recognise that smoke clearance is only undertaken when a fire has been extinguished since any attempt to clear smoke before a fire has been extinguished could introduce more air to the fire. Dedicated fixed smoke clearance trunking is to be of steel construction and both this and the fans are to be capable of operating at the temperatures of the exhaust gas from the extinguished fire but, in any case, not less than 250°C. Portable fans of suitable design may also be used with temperature resistant flexible trunking. Clearance of smoke is to be such that unaffected parts of the ship are not contaminated with smoke.

■ *Section 4*
Control and monitoring and electrical power arrangements

4.1 General

4.1.1 The control engineering arrangements are to comply with *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems* as applicable.

4.1.2 The equipment used in HVAC systems is to be provided with local control and monitoring arrangements.

4.1.3 Where isolation of equipment or systems can be carried out, means of indicating the status of isolation is to be provided at positions where the equipment and system can be operated and monitored.

4.1.4 Instrumentation to indicate the operational status of running and any standby equipment is to be provided locally and at any control station.

4.1.5 All pumps are to be provided with an indication of discharge pressure and a low discharge pressure alarm at each control station.

4.1.6 The power to all independently driven ventilation fans is to be capable of being stopped from position(s) outside the fire boundary which will always be readily accessible in the event of fire occurring in any space, as well as from the local control panel.

4.1.7 Electrical engineering arrangements are to comply with *Vol 2, Pt 9 Electrotechnical Systems*.

4.1.8 Refrigeration compressors are to be provided with the following instrumentation and automatic shutdowns:

(a) Indication of suction pressure (saturated temperature), including intermediate stage when applicable.
(b) Indication of discharge pressure (saturated temperature), including intermediate stage when applicable.
(c) Indication of lubricating oil pressure.
(d) Indication of cumulative running hours.
(e) Automatic shutdown in the event of low lubricating oil pressure.
(f) Automatic shutdown in the event of high discharge pressure which is to operate at a pressure in excess of normal operating pressure but not greater than 0,9 of the maximum working pressure.

(g) Automatic shutdown in the event of a low suction pressure.

4.1.9 For refrigeration compressors greater than 25 kW, the following instrumentation, additional to that required by *Vol 2, Pt 11, Ch 2, 4.1 General 4.1.8*, is to be provided:

(a) Indication of lubricating oil temperature.
(b) Indication of cooling water outlet temperature.
(c) Indication of suction and discharge temperatures.

4.1.10 Alarms are to be initiated in the event of the following fault conditions with refrigeration compressors:

(a) High discharge pressure.
(b) Low suction pressure.
(c) Low oil pressure.
(d) High discharge temperature.
(e) High oil temperature.
(f) Motor shutdown.

4.1.11 Refrigeration plants are to be provided with the following alarms:

(a) Failure of condenser cooling water pumps.
(b) High condenser cooling water outlet temperature.
(c) Failure of air cooler fans.
(d) High and low chilled water delivery temperatures.

4.1.12 Ventilation air heating/cooling plants are to be provided with the following instrumentation and alarms as applicable:

(a) Indication of heating/cooling medium temperature.
(b) Indication of delivery air temperature.

4.1.13 Filter units for ventilation systems for crew and embarked personnel installations are to be provided with the following instrumentation and alarms:

(a) Indication of differential air pressure across the filter unit.
(b) High differential air pressure alarm.

■ *Section 5*
Testing and trials

5.1 Testing

5.1.1 The requirements of the Rules relating to testing of pressure vessels, piping and related fittings including hydraulic testing are applicable. (*See Vol 2, Pt 8, Ch 2, 10 Hydraulic tests* and *Vol 2, Pt 7, Ch 1, 16 Testing*).

5.1.2 On completion, tanks and reservoirs for service and storage of system fluids are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

5.1.3 After installation on board, piping systems together with associated fittings that are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

5.1.4 Testing is to cover the following items:

(a) Verification of control, alarm, safety systems.
(b) Tests simulating failure of HVAC equipment to verify correct functioning of alarms and systems in service.
(c) Verification of accuracy, calibration and functioning of temperature control for HVAC systems.

5.2 Type testing

5.2.1 Evidence that the required performance of heating/cooling/filtration systems, pump and fan equipment is capable of being maintained under ambient and inclination operating conditions defined in *Vol 2, Pt 1, Ch 3, 4.4 Ambient reference conditions* and *Vol 2, Pt 1, Ch 3, 4.6 Inclination of ship* is to be provided by the manufacturer.

5.3 Trials

5.3.1 Trials are to be carried out to demonstrate that the capability of the HVAC systems meets the System Design Description. The trials are as far as practicable to be representative of the actual conditions to be encountered in service.

■ *Section 1* General requirements

1.1 General

1.1.1 This Chapter states the requirements for waste matter systems and arrangements installed in naval ships.

1.1.2 The requirements in this Chapter cover arrangements, equipment, and control systems necessary for effective functioning of waste matter systems on board a naval ship.

1.2 Scope

1.2.1 Waste matter systems included in this Chapter cover the following:

(a) Sewage waste
(b) Galley waste
(c) Grey water
(d) Black water
(e) Solid waste
(f) Medical, sanitary, oil contaminated and hazardous waste.

Waste materials related to naval ship military operations are outside the scope of these requirements.

1.2.2 Oily wastes from machinery and other spaces are within the scope of the **ENV** and **POL** class notations, *see Vol 3, Pt 2, Ch 2 Environmental Protection* and *Vol 3, Pt 3, Ch 6 Pollution Prevention*.

1.2.3 **Sewage waste** means:

(a) Drainage and other wastes from any form of toilets, urinals and WC scuppers.
(b) Drainage from medical premises (dispensary, sick, etc.) via wash basins, wash tubs and scuppers located in such spaces.
(c) Other wastes waters when mixed with drainages defined in (a) and (b).

1.2.4 **Galley waste** means drainage from galleys that may be contaminated with food or other organic waste that may give rise to smell.

1.2.5 **Grey water** means drainage from baths, showers, sinks and laundry systems.

1.2.6 **Black water** means drainage from sewage systems and chemical wastes that could constitute a recognised health and safety risk to persons on board.

1.2.7 For the purposes of treatment and disposal: **solid waste** means food waste, plastics, medical waste, sanitary waste, oily rags and other dry waste such as paper, glass, metal, rags (non-oily) and packing materials. Contaminated CBRN protective wear are not within the scope of this definition.

1.3 Documentation required for design review

1.3.1 Three copies of the plans and information stated in *Vol 2, Pt 11, Ch 3, 1.3 Documentation required for design review 1.3.2* is to be submitted to LR as applicable.

1.3.2 **System Design Description** A System Design Description of the waste systems, *see Vol 2, Pt 1, Ch 3, 3.5 System design description*.

1.3.3 **Waste treatment and disposal plan.** A plan detailing the intended handling and treatment of solid waste is to be provided on board the ship. The plan is to detail the waste treatment procedures for all categories of solid waste with respect to the following criteria:

(a) Estimate of total production of each waste type per crew member for a specified period for each specific ship's voyages/ missions.
(b) Processing facilities for solid waste matters, access and maintainability.
(c) Waste retention/storage facilities, including size and location on board the ship, access and separation.
(d) Overboard disposal of waste and permissions.
(e) Disposal of waste ashore and handling facilities.
(f) Treatment and handling of specialist waste, e.g. medical and oil contaminated waste.
(g) Hygiene.
(h) Waste segregation arrangements.

1.3.4 **Systems.** Plans in diagrammatic form showing piping arrangements, control systems and safeguards and electrical systems covered by this Chapter. The major component parts, pipe sizes, system flow rates and pressures together with capacities of pumps and plants and tanks are to be included. Any Standards or Design Guidance used for system design are to be stated.

1.3.5 **Compartments.** Plans showing the general arrangement of compartments, together with a description of the equipment and arrangements installed for handling, treatment, storage and disposal of waste and the electrical power supply systems. The plans are to indicate segregation and access arrangements for compartments and associated control rooms/ stations.

1.3.6 **Testing and trials procedures.** A schedule of testing and trials to demonstrate that systems are capable of operating as described in *Vol 2, Pt 11, Ch 3, 3 System arrangements*.

1.3.7 **Operating Manuals.** Operating Manuals are to be provided on board and submitted for information where requested by LR. The manuals are to include the following information:

(a) Particulars and a description of the systems.
(b) Operating instructions for the equipment and systems.
(c) Arrangements for the disposal of oily wastes from galleys.

■ *Section 2*
Construction and installation

2.1 Materials

2.1.1 Pipes, valves and fittings are, in general, to be made of steel, ductile cast iron, copper, copper alloy, or other approved ductile material suitable for the intended purpose. The use of plastics materials is also acceptable subject to any restrictions in *Vol 2, Pt 7, Ch 1, 11 Pipe connections*.

2.1.2 Where applicable, the materials are to comply with the requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements*.

2.1.3 The selection of materials in piping systems is to recognise the following details:

(a) Fluid properties, pressures and temperatures.
(b) Location and configuration.
(c) Compatibility of materials.
(d) Fluid flow rates and static conditions.
(e) Minimising corrosion and erosion through life of system.
(f) System survey, cleaning and maintenance requirements.

See Vol 2, Pt 7, Ch 1, 17 Guidance notes on metal pipes for water service for guidance notes on metal pipes for water services.

2.2 Pipe wall thickness

2.2.1 The minimum nominal wall thickness of steel, copper and copper alloy pipes are to be in accordance with *Vol 2, Pt 7, Ch 1 Piping Design Requirements*.

2.2.2 Special consideration will be given to the wall thickness of pipes made of materials other than steel, copper and copper alloy.

2.3 Piping and equipment — Selection and installation

2.3.1 Pressurised tanks are to be in accordance with *Vol 2, Pt 8, Ch 2 Other Pressure Vessels* or a recognised code.

2.3.2 Valves, flexible hose lengths, expansion pieces and pumps are to comply with the relevant requirements of *Vol 2, Pt 7, Ch 1, 12 Valves* (*see also Vol 2, Pt 11, Ch 3, 2.1 Materials* regarding selection of materials). The configuration of piping systems is to be arranged to minimise erosion and corrosion of pipe and equipment materials. Equipment used in waste piping systems is to be suitable for its intended purpose, and accordingly, wherever practicable, be selected from the *Lists of LR Type Approved Products* published by LR.

2.3.3 Pipes in piping systems are to be permanent pipes made with approved pipe connections to enable ready removal of valves, pumps, fittings and equipment. The pipes are to be efficiently secured in position to prevent chafing or lateral movement.

2.3.4 Suitable means for expansion is to be made, where necessary, in each range of pipes.

2.3.5 Efficient protection is to be provided for all pipes situated where they are liable to mechanical damage.

2.3.6 All moving parts are to be provided with guards to minimise danger to personnel.

2.4 Valves — Installation and control

2.4.1 Valves are to be fitted in places where they are at all times readily accessible.

2.4.2 All valves that are provided with remote control arrangements are to be arranged for local manual operation, independent of the remote operating mechanism. The local manual means of operation is to be readily accessible.

2.4.3 Relief valves are to be adjusted and bursting disks so selected that they relieve at a pressure not greater than the design pressure of the system. When satisfactorily adjusted, relief valves are to be protected against tampering or interference by wire with a lead seal or similar arrangement.

2.5 Coating of storage tanks and piping internal surfaces

2.5.1 The storage tanks and metallic piping and valves are to be lined internally with a corrosion control coating suitable for the containment and transfer of waste matter.

2.5.2 Corrosion control coatings are to be tested and certified as complying with standards specified by the Designer and Owner.

2.6 Plastics piping and flexible hoses

2.6.1 Subject to compliance with *Vol 2, Pt 7, Ch 1, 11 Pipe connections* and *Vol 2, Pt 7, Ch 1, 13 Flexible hoses*, and the relevant Sections of *Vol 2, Pt 7, Ch 2 Ship Piping System*, plastics piping may be used in piping systems for waste matter. Where storage tanks and metallic piping are constructed from materials that will not be affected by corrosion from waste matter, internal lining will not be insisted upon.

2.6.2 Plastics piping is to be selected in consultation with the manufacturers with regard to suitability with the proposed pipe system cleaning practice. Where storage tanks and metallic piping are constructed from materials that will not be affected by corrosion from waste matter, internal lining will not be insisted upon.

Section 3
System arrangements

3.1 Arrangements

3.1.1 The installation and arrangements of systems and equipment are to recognise the manufacturer's recommendations for the effective functioning of waste systems.

3.1.2 The arrangements for waste systems are to be such that they are capable of operating under all normal angles of heel and trim.

Normal angles of heel and trim are to be taken as:

(a) Ship on an even keel or has a list of not more than 5°.
(b) Ship on even trim or is trimmed not more than 5° for a ship up to 100 m in length. Where the length of the ship exceeds 100 m, the maximum trim may be taken as 500/L degrees where L = length of ship, in metres.
(c) The angles of heel and trim may occur simultaneously.

3.1.3 The piping system design for waste systems is to incorporate adequate fall and flow arrangements which exclude traps unless specifically required for system operation/cleaning. The determination of adequacy of fall and flow is to be made with reference to a suitable and proven design standard.

3.1.4 The piping system arrangements are to be such that they are capable of being cleaned and unblocked.

3.1.5 The processing/storage capacity of waste systems is to take into account the operational profile of the ship and its complement. For example, the ship may spend a prolonged period of time in littoral waters where sewage discharge overboard, treated or untreated, is prohibited by the relevant national authority and, therefore, adequate holding capacity may need to be provided.

3.1.6 The waste systems are to be of sufficient capacity to handle peak flows in addition to an average flow. Typically, peak flows can be three times the average hourly flow but this should be confirmed during the design stage.

3.1.7 Variations in the complement of the ship are to be taken into account but the system must be capable of satisfactory operation with the minimum number of persons on board when the ship is at sea.

3.1.8 If only one sewage treatment plant is fitted then arrangements are to be provided to allow essential maintenance work to be undertaken on this plant whilst retaining full use of the remainder of the sewage and waste water system.

3.1.9 Drains from medical facilities are to be led to the black water side of the sewage treatment plants or holding tanks.

3.1.10 Vents from wastes systems are to terminate outside the vessel. However, where a vessel is required to be capable of operating within an CBRN threat area, then these vents are to be capable of being reconfigured to vent inside the citadel via charcoal filters.

3.1.11 Overboard discharges are to be arranged such that they are clear of accommodation ladders, areas where boats are loaded/unloaded, etc.

3.1.12 Arrangements are to be made for the disposal of oily wastes stemming from food preparation in galleys. Systems intended for the disposal of such oily wastes are to be separate from other waste systems. Suitable notices are to be provided advising that oily wastes are not to be disposed of.

Section 4
Treatment of solid waste matter

4.1 General

4.1.1 Facilities are to be provided on board for the treatment and storage of all solid waste generated. In general, facilities are to be provided for the thermal destruction of solid waste on board to enable disposal of as much solid waste as possible when the ship is at sea.

4.1.2 Sufficient space is to be made available to store and secure all waste generated between sailing and next shore stop, or waste collection where there are no incineration facilities on board.

4.1.3 The storage facilities are to be sufficient in capacity for the storage of solid waste produced during the defined ship's missions and capability of any installed thermal destruction plant for solid waste disposal. This is to take into account voyages in special areas where disposal is prohibited.

4.1.4 The storage of solid waste is to be such that the waste is prevented from rotting, by provision of suitable cooling facilities where necessary. Alternatively, the waste may be packed such that no gases or odours are spread.

4.1.5 Independent and safe storage spaces are to be available for medical, sanitary, oil contaminated and other hazardous wastes to ensure that such wastes are kept separate from each other and other solid wastes.

4.1.6 Each storage space shall be provided with adequate ventilation capacity and insulated, where necessary. Cooling facilities to comply with *Vol 2, Pt 11, Ch 3, 4.1 General 4.1.4* may also be required. All spaces used for storage of solid waste are to be provided with fire detection equipment, and shelving within storage facilities are to be arranged in a grid so as to enable access for fire-fighting purposes.

4.1.7 Consideration shall be given to the location of treatment and storage rooms, in terms of separation from accommodation and communal areas. Similarly, waste treatment and storage spaces are to be located so as to facilitate the convenient handling of waste on board the ship, and its transfer ashore.

4.1.8 Solid waste treatment plant, such as food waste pulpers, compactors and shredders, are to be suitable for their intended function. The capacity of the waste processing equipment is to be sufficient to process the specified amount of waste. Equipment for wastes treatment is not to produce toxic fumes, heavy smoke or excessive noise when functioning.

4.1.9 The arrangements in waste storage spaces are to allow easy access for cleaning. Drains in solid waste storage and treatment spaces are to be easy to clean and should prevent waste/dirt entering the system. In selecting deck coating and covering materials, consideration is to be given to ease of cleaning, and impact and corrosion protection. Sufficient space is to be available on all sides of waste treatment equipment to allow maintenance access.

4.1.10 When the ship is in harbour, all stored waste is to be normally disposed of ashore or retained on board when reception facilities are not available.

■ *Section 5*
Control and monitoring and electrical power arrangements

5.1 General

5.1.1 The control engineering arrangements are to comply with *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems* as applicable.

5.1.2 Equipment used in waste systems is to be provided with local control and monitoring arrangements.

5.1.3 Where isolation of equipment or systems can be carried out, means of indicating the status of isolation is to be provided at positions where the equipment and system can be operated and monitored.

5.1.4 Instrumentation to indicate the operational status of running and any standby equipment is to be provided locally and at each control station.

5.1.5 All pumps are to be provided with an indication of discharge pressure and a low discharge pressure alarm at the control station.

5.1.6 The electrical engineering arrangements are to comply with *Vol 2, Pt 9 Electrotechnical Systems*.

5.1.7 The control, supervision and monitoring of thermal destruction units is to comply with *Vol 2, Pt 7, Ch 3, 9.4 Incinerators* where applicable.

Section 6
Testing and trials

6.1 Testing

6.1.1 The requirements of the Rules relating to testing of pressure vessels, piping and related fittings including hydraulic testing are applicable. *See Vol 2, Pt 8, Ch 2, 10 Hydraulic tests* and *Vol 2, Pt 7, Ch 1, 16 Testing*.

6.1.2 On completion, tanks and reservoirs for service and storage of system fluids are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

6.1.3 After installation on board, piping systems together with associated fittings that are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

6.1.4 Testing is to cover the following items:

(a) Verification of control, alarm, safety systems.
(b) Tests simulating failure of waste system equipment and pumps to verify correct functioning of alarms and systems in service.

6.2 Type testing

6.2.1 Evidence that the required performance of drainage and pumping equipment is capable of being maintained under ambient and inclination operating conditions defined in *Vol 2, Pt 1, Ch 3, 4.4 Ambient reference conditions* and *Vol 2, Pt 1, Ch 3, 4.6 Inclination of ship* is to be provided by the manufacturer.

6.3 Trials

6.3.1 Trials are to be carried out to demonstrate that the capability of the waste systems meets the System Design Description. The trials are as far as practicable to be representative of the actual conditions to be encountered in service.

Emissions Abatement Plant for Combustion Machinery

■ *Section 1*
General

1.1 Scope

1.1.1 The requirements of this Chapter apply to equipment fitted to combustion machinery in order to reduce emissions produced by the combustion of fuel. Such equipment is hereinafter referred to as emissions abatement plant. These requirements are intended to ensure that the emissions abatement plant is safe to operate and maintain and, additionally, where the combustion machinery provides power for Mobility and/or Ship Type systems, that failure of the emissions abatement plant does not result in an unacceptable loss or degradation of those systems. These requirements do not provide for the reliability or redundancy necessary to ensure continued operation of the emissions abatement plant, and thereby compliance with relevant emissions requirements, following failure of any equipment associated with the emissions abatement plant.

1.1.2 This Chapter is to be read in conjunction with the requirements for Machinery and Engineering Systems in *Vol 2, Pt 1 General Requirements*

■ *Section 2*
Functional requirements

2.1 General

2.1.1 The emissions abatement plant is to be capable of operating at the maximum output power of the combustion machinery to which it is connected. Where the machinery installation is configured such that it is not intended to operate all the combustion machinery connected to the emissions abatement plant simultaneously in normal operating conditions, this will be subject to special consideration and supported by the submission required by *Vol 2, Pt 12, Ch 1, 3.1 General 3.1.2*. For engines, the maximum power is as stated on the Engine International Air Pollution Prevention Certificate (EIAPPC) or an equivalent certificated engine rating for vessels which are not subject to MARPOL *Annex VI - Regulations for the Prevention of Air Pollution from Ships*.

2.1.2 Operation and maintenance of the emissions abatement plant is not to present a hazard to the ship’s occupants or to the environment and should not impair the functioning of Mobility category or Ship Type category systems.

2.1.3 Failure of the emissions abatement plant is not to present a hazard to the ship’s occupants and should not impair the functioning of Mobility category or Ship Type category systems.

2.1.4 Where the emissions abatement plant is connected to combustion machinery providing power for Mobility or Ship Type systems, failure, or the inability to operate the emissions abatement plant, is not to prevent the combustion machinery from delivering sufficient power to those Mobility or Ship Type systems to ensure the safe operation of the ship.

2.1.5 Any discharges overboard from the emissions abatement plant are to be in accordance with the requirements of National and International regulations, as applicable.

■ *Section 3*
Information to be submitted

3.1 General

3.1.1 The information required by this Section and the information required by *Vol 1, Pt 3, Ch 1, 4 Information required* is to be submitted.

3.1.2 A description of the emissions abatement plant and the abatement technique(s) used. This is to include details of the proposed combustion machinery operating configurations using a common emissions abatement system for multiple exhaust gas inlet streams and any limitations on the operation of combustion machinery connected to the emissions abatement system.

3.1.3 Where emissions abatement plant makes use of more than one abatement technique, e.g. separate means for reducing NOx and SOx, details demonstrating their compatibility with the combustion machinery and with each other.

3.1.4 Diagram(s) showing the process flows.

3.1.5 Details of the maximum and minimum ambient and sea-water temperatures within which the emissions abatement plant is to operate, and maximum and minimum ambient air temperature and humidity where applicable.

3.1.6 **Risk Based Analysis (RBA)**. The RBA required by *Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications 3.3.8* is to include consideration of the emissions abatement plant. It shall specifically detail the hazards associated with operation, maintenance and reasonably foreseeable failure of the emissions abatement plant and the means by which they are mitigated, demonstrating that the operation of Mobility and/or Ship Type systems shall not be impaired by such scenarios. *See also Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*.

3.1.7 Details of any fuel treatments, fuel additives or fuel emulsification used as a primary means of emissions abatement from combustion machinery, together with a manufacturer's letter confirming the suitability of combustion machinery to operate with such treatments and additives. Details are to include evidence that materials, fuel filtration and arrangements for the control of viscosity and temperature have been suitably modified, along with evidence of the suitability of fuel pumps and fuel valves for the treated fuel, with particular attention to viscosity, lubricity and stability, as applicable.

3.2 Materials

3.2.1 Details of the materials proposed for all types of construction.

3.3 Chemical substances

3.3.1 Details of the flammability, toxicity, corrosivity and reactivity of any chemicals used, together with details of any exothermic and hazardous reactions, particularly with regard to sea-water. This is to include effluent and sludge associated with emissions abatement plant and the corrosivity of wash water for wet scrubbing systems.

3.3.2 General arrangement of spaces where toxic or flammable liquids, gases, dusts or vapours are stored or may accumulate, indicating the hatches and other access openings.

3.3.3 Details of arrangements for loading, storage, transfer and disposal of chemicals, by-products or waste products; this is to include allowable maximum and minimum storage temperatures for substances which are sensitive to temperature.

3.3.4 General arrangement showing spaces maintained at an over-pressure to prevent the ingress of gases, dusts or vapours.

3.3.5 Details and arrangements of blowdown and bleed-off systems, where applicable, including quantities of chemicals, substances and effluents and the capacity and working pressure of tanks and receivers installed for the reception of such substances and effluents.

3.3.6 Arrangements for purging, gas freeing, inerting or otherwise rendering safe of the emissions abatement plant and storage facilities for chemicals, effluent and by-products associated with the plant.

3.3.7 The flow and return flow of chemicals, substances, effluent or by-products, including:

(a) Substance supply and product discharge, with details of the arrangements showing the location of shut-off valves and of the control and indicating stations.
(b) The process plant parameters and analysis of conditions under which emergency shutdown will be initiated.
(c) Measures to eliminate risk of process fluid reverse flows which could present a risk to propulsion engines, auxiliary engines and essential services.
(d) The proposed emergency procedures for controlled shutdown of the plant, i.e. depressurising, isolating and the arrangements for the continued operation of the essential services necessary to allow for such controlled shutdown under the emergency conditions identified in *Vol 2, Pt 12, Ch 1, 3.3 Chemical substances 3.3.7*, as applicable.

3.3.8 Proposals for the decontamination of the emissions abatement plant compartments for installations using chemicals, substances and/or producing effluent or by-products or where there is a possibility of generating hazardous substances during the operation of plant. These proposals are to include both normal operating requirements for decontamination (such as for carrying out maintenance) and post-incident decontamination.

3.3.9 Arrangement for the detection of liquids, gases and vapours where such substances could present a fire, explosion or health hazard.

3.4 Mechanical equipment

3.4.1 Details of mechanical equipment associated with the emissions abatement plant to be installed.

3.4.2 Details of any safety and pressure-relief devices and their discharge arrangements.

3.4.3 Plans showing the materials of construction, working pressures and temperatures, maximum and minimum exhaust gas flows, fuel quality parameters, maximum and minimum flow rates of any water, fluids, chemicals or substances required by the process, maximum effluent or by-product discharge rate resulting from the process.

3.4.4 Details of the arrangements for protecting the emissions abatement plant, its tanks and vessels against temperature, over-pressure and vacuum. Details are to include consideration of storage temperature requirements and, where applicable, tanks are to be maintained within the temperature limits of the chemicals and substances they contain so as to avoid risks of boiling, stress corrosion, freezing and other temperature-sensitive processes.

3.4.5 Details of the by-pass arrangements or, where considered unnecessary, evidence demonstrating that the emissions abatement plant is capable of continued operation with the expected gas flows. Evidence is to include conditions where the emissions abatement plant is in a shutdown condition, both as a result of emergency conditions and when shut down for normal operational reasons. This is to be supported by detailed proposals demonstrating material suitability and is to ensure that, where there is a risk of blockage, this can be monitored so as to ensure that remedial action can be taken before blockage presents a risk to both combustion machinery and emissions abatement plant operations.

3.5 Pressure vessels

3.5.1 Plans of any pressure vessels, including details of their supports. Diagrammatic plans for systems associated with emissions abatement process equipment as required by *Vol 2, Pt 8 Pressure Plant*, as applicable.

3.5.2 Details of the safety and pressure-relief devices and their discharge arrangements.

3.5.3 Stress calculations taking into account the ship linear and angular accelerations, roll and pitch amplitudes, ship flexure and wind loads, appropriate to any condition which may normally arise at sea.

3.6 Pumping and piping

3.6.1 Plans of the emissions abatement plant piping systems, showing the materials of construction, scantlings, support and expansion arrangements, together with the calculations.

3.6.2 Diagrammatic plans for systems associated with emissions abatement process equipment, as required by *Vol 2, Pt 7, Ch 1 Piping Design Requirements*, *Vol 2, Pt 7, Ch 2 Ship Piping System* and *Vol 2, Pt 7, Ch 3 Machinery Piping Systems*, as applicable.

3.6.3 Plans showing the arrangement and dimensions of main exhaust pipes, with details of flanges, bolts and weld attachments and particulars of the materials of the pipes, flanges, bolts and welding consumables.

3.6.4 Details of the safety and pressure-relief devices and their discharge arrangements.

3.6.5 Details of air and sounding pipes to tanks containing chemicals, substances and effluent.

3.6.6 The arrangements for the storage on board the ship, and the disposal, of bilge and effluent from the emissions abatement plant spaces, giving particular consideration to the risk of flooding as a result of emissions abatement plant failure. Recognition is to be given to the requirements of the appropriate National Authority.

3.7 Electrical and control equipment

3.7.1 General arrangement plan of the process plant, showing the location of the major items of electrical and control equipment.

3.7.2 The plans and particulars required by *Vol 2, Pt 9, Ch 1, 1.4 Documentation required for design review* and *Vol 2, Pt 9, Ch 1, 1.5 Documentation required for supporting evidence*.

■ *Section 4* Materials

4.1 General

4.1.1 The materials used in the construction of the emissions abatement plant and any associated chemical and effluent storage tanks are to be manufactured and tested in accordance with the requirements of the *Rules for the Manufacture, Testing and Certification of Materials.*

4.1.2 Materials used in piping systems are to comply with *Vol 2, Pt 7, Ch 1 Piping Design Requirements*, *Vol 2, Pt 7, Ch 2 Ship Piping System* and *Vol 2, Pt 7, Ch 3 Machinery Piping Systems* as applicable.

4.1.3 Materials used for wet scrubbers are to be constructed of corrosion-resistant material which is suitable for the expected operating temperatures of the scrubber and for the properties of wash water and chemicals used in the process, *see Vol 2, Pt 12, Ch 1, 3.3 Chemical substances 3.3.1*.

4.1.4 Materials used for selective catalytic reduction reactors are to be constructed of corrosion-resistant material which is to be suitable for the expected operating temperatures as well as the corrosive properties of ammonia and other chemicals associated with the chemical conversion process where applicable, *see Vol 2, Pt 12, Ch 1, 3.3 Chemical substances 3.3.1*.

4.1.5 Materials used for the construction of tanks for chemical substances associated with emissions abatement plant are to be suitable at the temperature and pressure for the chemical substances to be carried in accordance with recognised standards. Where it is proposed to use corrosion-resistant tank lining or coating then such lining and coatings are to be confirmed as being suitable for the expected operating temperatures and corrosive properties of the chemicals to be carried within the tank.

4.1.6 Materials used for the construction of tanks for wash water and effluent are to be suitable for the expected corrosivity and temperature of wash water and effluent to be contained within such tanks. Where it is proposed to use corrosion-resistant tank lining or coating then such lining and coatings are to be confirmed as being suitable for the expected operating temperatures and corrosive properties of wash water and effluents.

■ *Section 5* Hull construction

5.1 General

5.1.1 The hull structure is to comply with the relevant requirements of *Vol 1, Pt 3 Design Principles and Constructional Arrangements*, *Vol 1, Pt 4 Military Design and Special Features*, *Vol 1, Pt 5 Environmental Loads* and *Vol 1, Pt 6 Hull Construction in Steel*, except where stated otherwise in this Section.

5.1.2 Independent substance and effluent tanks are to be protected from mechanical damage. This may be achieved either by installation in spaces where there are no cargo or vehicle movements and where no heavy lifting operations are expected, or by mechanical protection if installed in spaces where such operations may take place.

5.1.3 Where necessary, the probable temperature variations during operations and the thermal stress considerations are to be stated. Where it is necessary either to heat or cool chemical storage tanks, the arrangements are to utilise either active pipe coils or ducts for circulating a heating or cooling medium within the chemical storage tank or a heat exchanger through which the chemical and a heating or cooling medium are circulated. Active heating and cooling systems are to have capacity such that the chemical in the designated tanks can be maintained within the specified temperature limits, *see Vol 2, Pt 12, Ch 1, 3.3 Chemical substances 3.3.3*, *Vol 2, Pt 12, Ch 1, 3.4 Mechanical equipment 3.4.4* and *Vol 2, Pt 12, Ch 1, 7.1 General 7.1.10*, under the following conditions:

	Heating systems	Cooling systems
Seawater temperature	0°C	32°C
Air temperature	5°C	45°C

Heating or cooling media are to be suitable for use with the specific chemical and consideration is to be given to the surface temperature of heating coils or ducts to avoid dangerous reactions from localised overheating or overcooling of chemicals. Heating or cooling systems are to be provided with valves to isolate the system for each tank and to allow manual regulation of flow along with a means for measuring the cargo temperature.

5.1.4 Where independent tanks are used for chemical substances, these are to be arranged so as to contain leakage. This may be achieved by using a double skinned storage tank, by means of a spill containment bund or by placing the tank in a dedicated compartment. Where a bund is to be used, it is to comply with the following:

(a) the bund is dimensioned so as to contain 1,5 times the maximum contents of the tank, ensuring that consideration has also been given to the angle of inclination requirements for main and auxiliary machinery in *Table 3.4.2 Inclinations* in*Vol 2, Pt 1, Ch 3, 4 Operating conditions*; or

(b) there is a drain arrangement meeting the requirements of *Vol 2, Pt 12, Ch 1, 5.1 General 5.1.6*; or

If the tank is located in a dedicated compartment then the compartment is to contain no equipment other than that required by the tank with permanent access and floor plates positioned above the liquid level if the tank were to discharge its full contents into the compartment. Any valves, equipment and emergency stop functions are to be operable from outside this compartment and are to meet the requirements of *Vol 2, Pt 12, Ch 1, 5.2 Location service and control spaces*.

Tanks and spill containment arrangements are to be fitted with alarms and safeguards, in accordance with *Table 1.9.1 Machinery emissions to air abatement plant: alarms and safeguards*.

5.1.5 Proposals are to be made for the dimensioning of containment arrangements, relative to the potential leakage which may require containment. Where it is not practicable to contain fully the potential leakage and where this leakage can pose a hazard to personnel, proposals are to be submitted, demonstrating that leakage will be transferred to a suitable retention tank, and the means of transfer shall be capable of operating in a dead ship condition and shall be fitted with a flow detection alarm, in accordance with *Table 1.9.1 Machinery emissions to air abatement plant: alarms and safeguards*.

5.1.6 Tanks are to be arranged such that any residues and slops can be pumped out, drained or otherwise removed from the tank without exposing personnel to these residues and slops.

5.1.7 Chemical tanks containing substances which are categorised as a safety hazard in Chapter 17 of the Rules for Ships for Liquid Chemicals (designated by letter "S" in column d) are not to be located in the same space as essential machinery and equipment.

5.1.8 Arrangements for venting and gas-freeing chemical tanks required by emissions abatement plant are to meet the requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements*, *Vol 2, Pt 7, Ch 2 Ship Piping System*, *Vol 2, Pt 7, Ch 3 Machinery Piping Systems* as applicable and are to be independent of the air pipes and venting systems of other tanks and/or compartments of the ship. Tank venting systems are to minimise the possibility of chemical vapour accumulating about the decks, entering accommodation, service and machinery spaces and control stations and, in the case of flammable vapours, entering or collecting in spaces or areas containing sources of ignition. Tank venting systems are to be arranged to prevent entrance of water into the chemical tanks. The venting systems shall be connected to the top of each chemical tank and as far as practicable are to be self-draining back to the chemical tanks under all normal operational conditions of list and trim.

5.1.9 Tank vent piping connected to cargo tanks of corrosion-resistant material, or to tanks which are lined or coated to provide corrosion resistance, are to be similarly lined or coated or constructed of corrosion-resistant material.

5.2 Location service and control spaces

5.2.1 Where flammable or toxic chemicals, gases or vapours are present, as identified in*Vol 2, Pt 12, Ch 1, 3.3 Chemical substances 3.3.1* and *Vol 2, Pt 12, Ch 1, 3.3 Chemical substances 3.3.2*, service and control stations essential to the operation of the plant are to meet the requirements of *Vol 2, Pt 12, Ch 1, 9.1 General 9.1.4*, and should, wherever possible, be located so that access thereto is from a defined safe space. If such a location is not possible, the station is to be specially ventilated.

5.2.2 Arrangements are to be made in spaces occupied by emissions abatement plant so that substances which are flammable, corrosive, toxic or are likely to present a hazard due to reaction when mixed are kept separate unless they are fully contained within a part of the emissions abatement system which has been designed for the safe mixing of such substances.

5.3 Integrity of water and gastightness between compartments

5.3.1 Where integrity of water or gastightness is required between compartments containing the plant, it is to be maintained in way of pipe tunnels or duct keels where these traverse such compartments.

5.3.2 Installations and the spaces in which they are installed are to be, in all cases, compliant with applicable National and International requirements for prevention, detection and extinction of fire.

5.4 Plant support structure

5.4.1 Decks and other structures supporting the plant are, in general, to comply with the requirements of *Vol 1 Ship Structures*. Such structures can, however, be considered on the basis of an agreed uniformly distributed loading in association with local loads at plant support points, provided that adequate transverse strength of the ship is maintained.

5.4.2 Where the nature and dispositions of heavy plant items are such that forces on the ship and support structure due to ship motions are significant (whether underway with or without working fluids, or moored with working fluids), calculations of the loading and the structural response are to be submitted.

5.5 Loading due to wave-induced motions

5.5.1 In cases where the mass distribution of large columnar equipment items is such that the centre of action of the dynamic force differs significantly from the centre of gravity of the item, due account of this is to be taken in the calculation of the forces and moments at the support positions.

5.6 Integrity of weather deck

5.6.1 The integrity of the weather deck is to be maintained. Where items of plant penetrate the weather deck and are intended to constitute the structural barrier to prevent the ingress of water to spaces below the freeboard deck, their structural strength is to be equivalent to the Rule requirements for this purpose. Otherwise, such items are to be enclosed in superstructures or deckhouses fully complying with the Rules.

■ *Section 6*
Mechanical equipment

6.1 General

6.1.1 Emissions abatement plant associated with diesel engines and gas and steam turbines is to comply with the requirements of *Vol 2, Pt 2, Ch 1 Reciprocating Internal Combustion Engines*, *Vol 2, Pt 2, Ch 2 Gas Turbines* and *Vol 2, Pt 2, Ch 3 Steam Turbines* respectively, as applicable.

6.1.2 The mounting arrangements for the equipment are to be capable of withstanding the forces and moments stated in *Vol 2, Pt 12, Ch 1, 5.4 Plant support structure* and *Vol 2, Pt 12, Ch 1, 5.5 Loading due to wave-induced motions*.

6.1.3 The design is to take account of the risk of fire or explosion hazards which may arise from deposition of chemicals, unburnt fuel, particulates or any by-products of chemical reactions which may arise during normal operation.

6.1.4 The emissions abatement plant is to be:

(a) capable of being started in a hot condition without risk of failure due to thermal shock. This is to be demonstrated by means of submitting test reports for the materials of construction which provide evidence that the materials can accommodate the thermal stresses associated with hot starting; or

(b) provided with a soft start which prevents thermal shock. This may be achieved by means of a by-pass arrangement or by means of water flow control.

6.1.5 Safety or pressure-relief devices are to discharge to places which will not present a hazard to the ship's occupants or to any machinery.

6.1.6 Where bursting discs or rupture panels are used as safety and pressure-relief devices, these are to be dimensioned and designed in accordance with a recognised National or International Standard.

6.1.7 Where it can be expected that there will be deposition of materials, caking and waste, arrangements are to be provided for the safe cleaning of such systems.

6.1.8 Where there is a possibility of operating conditions in the system falling below the dew point temperature of any gases or vapours present in the system, suitable drains are to be provided to permit the discharge of any condensate formed.

6.2 By-pass or equivalent arrangements

6.2.1 The emissions abatement plant is to be provided with a by-pass capable of transmitting the minimum and maximum exhaust gas flows from the combustion machinery to which it is connected. Where a by-pass is considered unnecessary, the emissions abatement plant is to be capable of safely transmitting the minimum and maximum exhaust gas flows with the emissions abatement plant out of operation, such that the combustion machinery to which it is connected can continue to operate.

6.2.2 Where a by-pass is fitted, there is to be a flow path for exhaust gas at all times.

6.2.3 A means of measuring differential pressure across the emissions abatement plant is to be provided.

6.3 Shared emissions abatement plant

6.3.1 Where the emissions abatement plant is connected to more than one item of combustion machinery, valves or equivalent means of isolating the exhaust systems of individual items of combustion machinery from common manifolds are to be provided to prevent reverse flow of exhaust gas into the exhaust manifolds of combustion machinery which has been shut down.

6.3.2 Where isolating valves are fitted, a means to verify the effectiveness of the isolation is to be provided.

6.4 Maintenance of back-pressure

6.4.1 The exhaust back-pressure, after installation of the emissions abatement plant, is to remain within the allowable limits stated by the combustion machinery manufacturers under all expected operating conditions, unless it is intended to operate the system at a negative pressure by means of an induced draught fan.

6.4.2 Where an induced draught fan is fitted to maintain the required exhaust back-pressure, failure of the fan is not to prevent the combustion machinery from operating.

6.4.3 Where the emissions abatement plant is fed from multiple exhaust gas inlet streams, the back-pressure is to be maintained within the allowable limits provided by the combustion machinery manufacturers for all operating configurations.

6.5 Protection of combustion machinery

6.5.1 Measures are to be implemented to ensure that water from the emissions abatement plant cannot flow back into the combustion machinery.

6.5.2 Means are to be provided for protecting critical combustion machinery components from foreign object damage resulting from failure of, or damage to, the emissions abatement plant. Where such damage is considered unlikely, evidence is to be submitted accordingly.

6.5.3 Where chemicals or substances are injected into the exhaust gas stream before turbocharger(s) or emissions abatement plant are fitted, this is not to present a risk of damage, chemical attack or performance degradation to the machinery with which they are associated.

6.5.4 Where fuel treatments, additives or emulsification are used as a primary means of abating exhaust emissions, machinery is to be compatible with such additives, treatments and emulsified fuel.

6.5.5 Where exhaust gas is recirculated as a means of emission abatement, the recirculated exhaust gas is not to cause fouling and corrosion of critical machinery components and scavenge air temperature is to be maintained at a level which does not adversely affect engine performance.

6.5.6 Where a wet scrubber is used to clean and cool recirculated exhaust gas, the scrubber is to satisfy the requirements of *Vol 2, Pt 12, Ch 1, 7.1 General 7.1.9*.

■ *Section 7* **Pumping and piping**

7.1 General

7.1.1 Pipe work and transfer systems which may carry chemical substances are to meet the requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements*, *Vol 2, Pt 7, Ch 2 Ship Piping System* and *Vol 2, Pt 7, Ch 3 Machinery Piping Systems*, as applicable. Lining steel pipe systems with corrosion-resistant materials is subject to special approval. The elasticity of the lining is not to be less than that of the supporting boundary material.

7.1.2 Pipe systems carrying sea-water or fresh water are to meet the requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements*, *Vol 2, Pt 7, Ch 2 Ship Piping System* and *Vol 2, Pt 7, Ch 3 Machinery Piping Systems*. Where there is a risk of fresh-water or sea-water systems becoming contaminated with process chemicals, substances or effluent, pipe systems are to comply with *Vol 2, Pt 12, Ch 1, 7.1 General 7.1.1*.

7.1.3 Chemical transfer and control arrangements are to be provided with one stop-valve capable of being manually operated on each tank filling and discharge line, located near the tank penetration, plus one stop valve at each chemical-hose loading connection. The stop valve for the chemical tank discharge line is additionally to the quick closing type and is to meet the requirements of *Vol 2, Pt 12, Ch 1, 9.1 General 9.1.6*.

7.1.4 Bilge and effluent pumping and piping systems in the emissions abatement plant spaces are to be constructed of materials suitable for any chemicals or substances used by the emissions abatement plant, any effluent that is produced or any combination of substances on board which might result from accidental admixture.

7.1.5 Arrangements are to be provided for the control of the bilge and effluent pumping and piping system. They are to be installed in the emissions abatement plant spaces from within these spaces and also from a position outside the spaces.

7.1.6 Bilge and effluent pumping and piping systems for hazardous materials should, wherever possible, be installed in the space associated with the particular hazard.

7.1.7 Where chemicals or wash water are injected into exhaust piping then the exhaust piping is to be suitable for such chemicals and wash water, *see Vol 2, Pt 12, Ch 1, 3.3 Chemical substances 3.3.1*.

7.1.8 Where filters are used, they are to be capable of being removed for cleaning and replaced safely without interrupting emissions abatement plant or combustion machinery operations.

7.1.9 Where scrubbers are used, the following apply:

(a) Closed loop wet scrubbers are to have natural gravity fall drainage from the wet sump of the scrubber to the process tank or circulating pump suction, with the drain line dimensioned to accommodate 125 per cent of the maximum pumping capacity of the installed water pump(s). No valves are to be fitted to the drain line from the scrubber sump to the process tank unless it can be demonstrated that suitable precautions are in place to prevent the possibility of the scrubber filling with water and reverse-flowing into the combustion machinery exhaust duct. Where a valve is fitted to this line, the system is to be protected as for the overboard discharge valve of an open loop system, in accordance with *Table 1.9.1 Machinery emissions to air abatement plant: alarms and safeguards*.

(b) For open loop wet scrubbers, the overboard discharge valve and any other sea-water valves downstream of the scrubber are to be protected in accordance with *Table 1.9.1 Machinery emissions to air abatement plant: alarms and safeguards*. The sea suction valve(s) are also to have position indicators which are to give remote indication of valve position. The scrubber is to be mounted above the waterline under all normal ship operating conditions to prevent sea-water ingress into the scrubber.

(c) For wet scrubbing systems (open loop and closed loop), an overflow line is to be fitted to prevent the risk of reverse flow of water to combustion machinery. This overflow is to be dimensioned to accommodate 125 per cent of maximum capacity of installed water pumps and is to have no impairment to flow. This overflow line is to be directed to the process tank in closed loop or hybrid installations. On open loop installations, it is to be directed overboard. The overboard discharge is to have an

effective means of preventing reverse flow of seawater. Alternative arrangements to prevent the risk of reverse flow are subject to special consideration.

(d) Overboard discharge connections from scrubbers are to be positioned below the lowest operating waterline and are to be internally protected from effluent-induced corrosion.

7.1.10 Where applicable, tanks are to be maintained within the temperature limits of the chemicals and substances they contain so as to avoid risks of boiling, stress corrosion, freezing and other temperature-sensitive processes.

■ *Section 8* Pressure vessels

8.1 General

8.1.1 Pressure vessels are to be in accordance with the requirements of the relevant Sections of *Vol 2, Pt 8, Ch 1 Steam Raising Plant and Associated Pressure Vessels* or *Vol 2, Pt 8, Ch 2 Other Pressure Vessels* as applicable, or with agreed Codes and specifications normally used for similar plants in land installations, suitably modified and/or adapted for the Marine Environment.

8.1.2 Mounting arrangements are to take account of forces and moments generated at the supports. Mounting arrangements are to take account of thermal expansion and contraction.

8.1.3 Access is to be provided for inspection and checking of mountings, fittings, controls and pressure-relief devices.

8.1.4 Arrangements are to allow the pressure settings of pressure-relief devices to be checked.

8.1.5 Where provision is made to isolate pressure-relief devices from pressure vessels for maintenance purposes, at least two such pressure-relief devices are to be fitted. The isolating or blocking valves are to be arranged such that at least one pressure-relief device remains operational at all times.

■ *Section 9* Electrical and control equipment

9.1 General

9.1.1 Electrical system(s) associated with emissions abatement plant are to meet the requirements of *Vol 2, Pt 9 Electrotechnical Systems*.

9.1.2 Control system(s) associated with the emissions abatement plant are to meet the requirements of *Vol 2, Pt 9, Ch 1 General Requirements for the Design and Construction of Electrotechnical Systems*.

9.1.3 Electrical and control equipment associated with the emissions abatement plant is to be compatible with any chemicals used and meet the requirements of *Electrical Installations* of the Rules for Ships for Liquid Chemicals.

9.1.4 Where flammable or toxic chemicals, gases or vapours are present, as identified in *Vol 2, Pt 12, Ch 1, 3.3 Chemical substances 3.3.1* and *Vol 2, Pt 12, Ch 1, 3.3 Chemical substances 3.3.2*, or where there is a possibility that flammable gases and vapours can be produced as a result of deviations from normal operation, the defining of hazardous zones is to be in accordance with *Vol 2, Pt 9, Ch 5, 4 Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts*.

As a minimum, for the detection of gas and vapours, a gas detection system is to be fitted which is to activate at a concentration corresponding to the substance safe occupational level. The locations of the detectors are to be determined relative to the layouts of the individual spaces and are to be indicated on the plan submission required by *Vol 2, Pt 12, Ch 1, 3.3 Chemical substances 3.3.9*. Where it is not practicable to install a detection system, alternative proposals are to be submitted to ensure the safety of persons from exposure to such substances.

9.1.5 Process tanks which form part of the operating loop of any emissions abatement equipment are to have a high-level alarm, in accordance with *Table 1.9.1 Machinery emissions to air abatement plant: alarms and safeguards*. Effluent tanks which are not part of the normal process loop and which are used for storage of effluent or substances prior to discharge from the vessel are to be protected, in accordance with *Table 1.9.1 Machinery emissions to air abatement plant: alarms and safeguards*. Tank

alarm and trip sensors are to be positioned at a point that will allow the system shutdown to operate before the tank overflows, based on the maximum design flow rates and shutdown response time. Where a low level is identified as presenting a risk to crew or machinery, tanks are to have a low-level alarm and a low-level trip. These are to be positioned so as to operate before a low level results in a hazardous condition, based on system design flow rates and a system shutdown response time.

Table 1.9.1 Machinery emissions to air abatement plant: alarms and safeguards

Item	Alarm	Note
Exhaust gas outlet temperature	High	
Exhaust gas inlet temperature	High	
Exhaust gas inlet temperature	Low	Only for selective catalytic reduction
Differential pressure across abatement plant unit	High	
Abatement plant by-pass valve in exhaust duct	Valve Movement	*See* Note 1
Machinery exhaust duct isolating valve	Valve Movement	*See* Note 2
Wet emissions abatement unit overboard discharge Valve	Closed	Emissions abatement plant is to be shut down automatically, *see* Note 6
Wet emissions abatement unit overflow line flow detection	Flow Present	Emissions abatement plant is to be shut down automatically, *see* Note 6
Wet emissions abatement water pressure	Low	
Wet emissions abatement unit water level	1st Stage high	
Wet emissions abatement unit water level	2nd Stage high	Emissions abatement plant is to be shut down automatically, *see* Note 6
Chemical feed flow	1st Stage low	
Chemical feed flow	2nd Stage low	Chemical feed pump is to be shut down automatically
Process tank level	1st Stage high	*See* Note 3
Process tank level	2nd Stage high	Emissions abatement plant is to be shut down automatically, *see* Note 3
Chemical storage tank level	1st Stage high	
Chemical storage tank level	2nd Stage high	
Chemical storage tank level	Low	
Chemical storage tank temperature	High	*See* Note 4
Chemical storage tank temperature	Low	*See* Note 4
Chemical tank containment bund level	High	Tank outlet quick-closing valve is to close automatically, *see* Note 5
Chemical tank containment drain line flow detection	Flow present	Tank outlet quick-closing valve is to close automatically, *see* Note 5
Exhaust gas recirculating fan failure	Failure	

Recirculating exhaust gas temperature return to engine	High	
Induced draught fan failure	Failure	Where fitted
Note 1 Only where a by-pass valve is fitted, *see Vol 2, Pt 12, Ch 1, 3.4 Mechanical equipment 3.4.5*. This valve shall open to the by-pass position as part of the unit shutdown logic. Note 2 Only where fitted, *see Vol 2, Pt 12, Ch 1, 6.3 Shared emissions abatement plant 6.3.1*. Note 3 The process tank is any tank forming part of a wet abatement system flow loop or effluent tanks which receive bleed-off from the main flow loop, or such tanks not forming part of the system flow loop but which are essential for operation of the system, including those on exhaust gas recirculating installations, *see Vol 2, Pt 12, Ch 1, 7.1 General 7.1.9*. Where low level can present a hazard, process tanks are also to have low-level protection. Note 4 Where chemical substances are to be kept within a defined temperature range, alarms will be fitted, based on the allowable temperature range, *see Vol 2, Pt 12, Ch 1, 3.4 Mechanical equipment 3.4.4 Vol 2, Pt 12, Ch 1, 5.1 General 5.1.2* and *Vol 2, Pt 12, Ch 1, 7.1 General 7.1.10*. Note 5 Chemical spillage detection alarm will depend on the means of spill containment fitted, see *Vol 2, Pt 12, Ch 1, 5.1 General 5.1.2*. Note 6 Wet emissions abatement unit shall include such systems fitted as part of the exhaust gas recirculating installations.		

9.1.6 An Emergency Stop Function (E-Stop) is to be provided, which is to:

- Close quick-closing valves on chemical tank(s) (where applicable).
- Stop chemical feed pump(s) (where applicable).
- Where fitted, open exhaust gas cleaning by-pass valve.
- Stop scrubber water pumps and close scrubber water inlet valve (where applicable).

9.1.7 The E-Stop function is to be capable of being actuated from the machinery control room, the navigating bridge and from within compartments containing exhaust gas cleaning plant. In order to mitigate the risk of chemical release, spaces containing chemical storage tanks or chemical pumping equipment are to have an emergency stop which is to shut down the chemical supply to the emissions abatement plant. Other parts of the emissions abatement plant such as wash water pumps need only be stopped by this emergency stop where loss of chemical injection could result in further risks arising from operating the plant without chemical injection. This is to form part of the submission required in *Vol 2, Pt 12, Ch 1, 3.1 General 3.1.6*.

9.1.8 Alarms and safeguards are to be provided for the critical system parameters in order to avoid danger to crew and machinery. As a minimum, the alarms and safeguards listed in*Table 1.9.1 Machinery emissions to air abatement plant: alarms and safeguards* are to be fitted. Alarms and trip protection required by these Rules are to be independent of each other. Where the Risk Based Analysis required by *Vol 2, Pt 12, Ch 1, 3.1 General 3.1.6* identifies that additional alarms and safeguards are required, these are to be implemented.

9.1.9 Where emissions abatement plant makes use of chemical substances, a means of monitoring abnormal flows of such chemicals is to be provided.

Contents

Volume 3

Ice Navigation - First-Year Ice Conditions

■ *Section 1* General requirements

1.1 Application

1.1.1 Where additional strengthening for the hull is fitted in accordance with the requirements of *Vol 3, Pt 1, Ch 1, 2 Hull strengthening requirements* and the machinery and engineering systems are in accordance with *Vol 3, Pt 1, Ch 1, 3 Machinery and engineering systems*, an appropriate Ice Class notation will be assigned. *See Vol 1, Pt 1, Ch 2, 3.10 Other notations 3.10.13*.

1.1.2 The requirements for navigation in ice stated in *Vol 3, Pt 1, Ch 1, 2 Hull strengthening requirements* and *Vol 3, Pt 1, Ch 1, 3 Machinery and engineering systems* are intended for ships operating in first-year ice irrespective of whether assistance from ice breakers is anticipated. They are not intended for ships designed to operate in multi-year ice conditions.

1.2 Documentation required for design review

1.2.1 Plans and information showing compliance with the hull structure and machinery and engineering systems requirements are to be submitted for approval. The plans and information are to indicate compliance with *Vol 3, Pt 1, Ch 1, 2 Hull strengthening requirements* and *Vol 3, Pt 1, Ch 1, 3 Machinery and engineering systems* and the information is to be incorporated in the plans and information submitted for approval in open water service conditions for the relevant Chapters in *Vol 1 Ship Structures* and *Vol 2 Machinery and Engineering Systems*.

■ *Section 2* Hull strengthening requirements

2.1 Application

2.1.1 Where the notation '**Ice Class 1AS, 1A, 1B**, or **1C**' as specified in *Vol 1, Pt 1, Ch 2, 3.10 Other notations 3.10.13* is desired, the ship is to comply with the requirements of this Section, in addition to those for sea-going service, so far as they are applicable.

2.1.2 The vertical extent of the ice strengthening is related to the ice light and ice load waterlines, which are defined in *Vol 3, Pt 1, Ch 1, 2.2 Definitions* . The maximum and minimum Ice Class draughts at both the fore and aft ends will be stated on the Class Certificate.

2.1.3 The ballast capacity of the ship is to be sufficient to give adequate propeller immersion in all ice navigating conditions without trimming the ship in such a manner that the actual waterline at the bow is below the ice light waterline.

2.1.4 Fresh-water and sea-water ballast tanks, the tops of which are situated above the minimum operating condition waterline and adjacent to the shell, and which are intended to be used in ice and cold navigation conditions, are to be provided with means to prevent freezing. It is to be demonstrated that such means protect against the following:

(a) Hull structural damage caused by tank contents being pumped from beneath a layer of ice, thereby drawing a vacuum into the tank.
(b) Hull structural damage caused by ice expansion.
(c) Tank internal piping and other components being damaged by ice expansion or blockage by ice.

(d) Tank internal piping and other components being mechanically damaged by falling pieces of ice.

Heating coils are considered effective means for tanks entirely above the waterline. Heating coils, continuous circulation, air bubbling or alarms and instrumentation are considered effective means for tanks partially below the waterline. Alternatively, submission of documentary evidence of service experience, testing, calculations or a combination thereof may be used to demonstrate that the above hazards have been mitigated.

2.1.5 The requirements of this Section are formulated for both transverse and longitudinal framing systems but it is recommended that, whenever practicable, transverse framing is selected.

2.1.6 The requirements of this Section assume that when approaching ice infested waters the ship's speed will be reduced appropriately. The vertical extent of ice strengthening for ships intended to operate at speeds exceeding 15 knots in areas containing isolated ice floes will be specially considered.

2.1.7 An icebreaking ship is to have a hull form at the fore end adapted to break ice effectively. It is recommended that bulbous bows are not fitted to Ice Class **1AS** ships.

2.1.8 The stern of an icebreaking ship is to have a form such that broken ice is effectively displaced.

2.1.9 Where it is desired to make provision for short tow operations, the bow area is to be suitably reinforced. Similarly, ice breakers may require local reinforcement in way of the stern fork.

2.2 Definitions

Note *see Figure 1.2.1 Regions and zones (First year ice conditions)*

2.2.1 The **Ice Deep Waterline** corresponds to the Deep Draught Waterline. Where specially requested, an Ice Deep Waterline may be specified which differs from the foregoing, but corresponds to the deepest condition in which the ship is expected to navigate in ice. *See Vol 1, Pt 3, Ch 1, 5.3 Margins* for margins.

2.2.2 The **Ice Light Waterline** is that corresponding to the lightest condition in which the ship is expected to navigate in ice. However, it is recommended that the minimum draught at the fore end is not to be less than:

$$T_f = \left(1,5 + 0,1\sqrt[3]{\Delta}\right)h\ m$$

where

h = the nominal ice thickness, in metres, associated with the desired Ice Class, *see Vol 1, Pt 1, Ch 2, 3.10 Other notations 3.10.13*.

Δ = displacement as defined in *Vol 3, Pt 1, Ch 1, 2.2 Definitions 2.2.11*.

2.2.3 The Ice Deep Waterline and the Ice Light Waterline are to be indicated on the plans.

2.2.4 The **Main Ice Belt Zone** extends vertically above and below the waterline defined in *Vol 3, Pt 1, Ch 1, 2.2 Definitions 2.2.1* and *Vol 3, Pt 1, Ch 1, 2.2 Definitions 2.2.2* by the distances shown in *Table 1.2.1 Vertical extent of main ice belt zone*. For ships fitted with a bulbous bow, the vertical extent of the Main Belt Zone will be suitably increased.

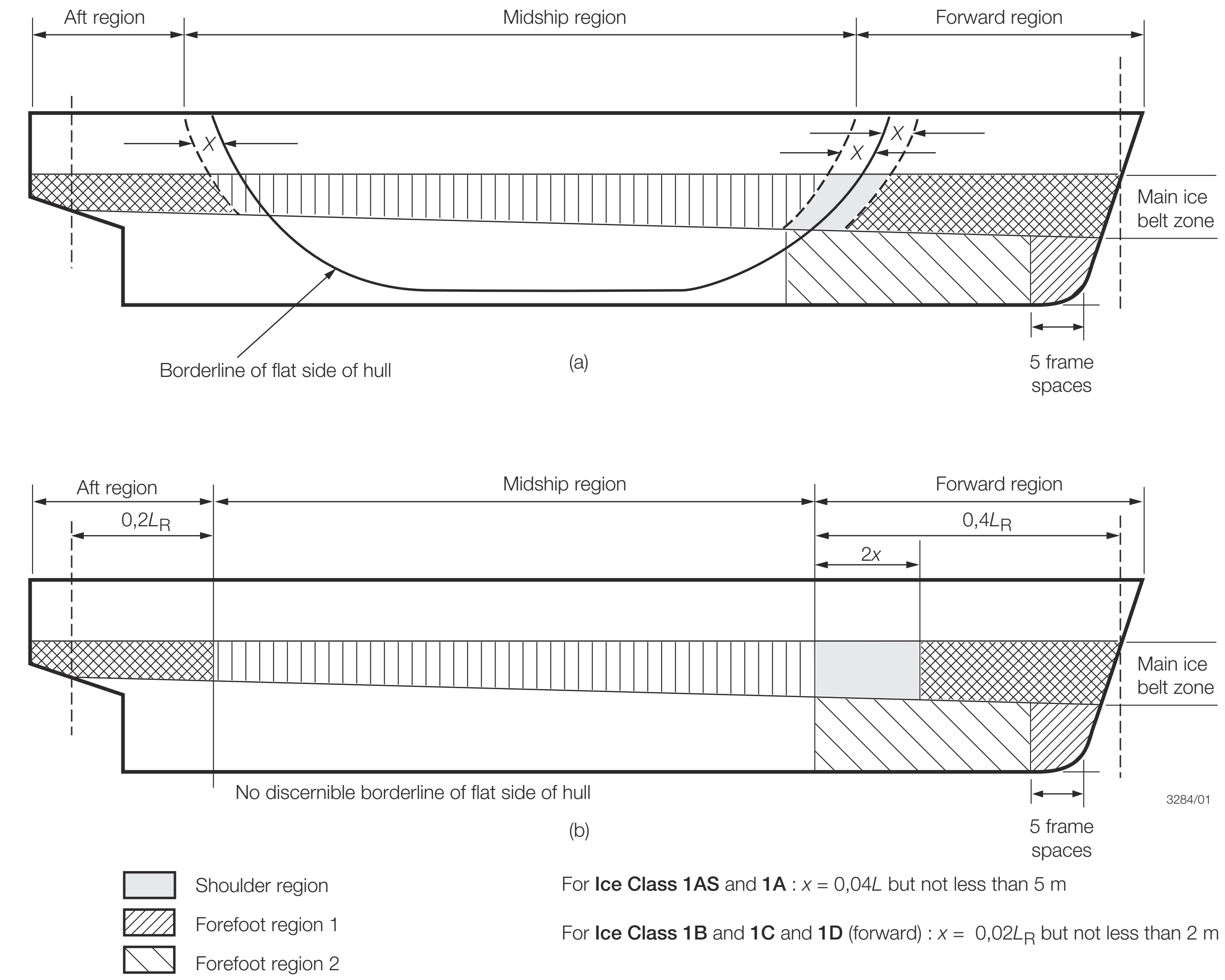


Figure 1.2.1 Regions and zones (First year ice conditions)

Table 1.2.1 Vertical extent of main ice belt zone

Class	Above Ice Load Waterline (mm)	Below Ice Light Waterline (mm)
1AS	600	750
1A	500	600
1B	400	500
1C	400	500

2.2.5 The **Forward Region** extends from the stem to aft of the forward borderline of the flat side of the hull by a distance equal to the greater of $0{,}04L_R$ or 5 m for ice classes **1AS** and **1A**, or the greater of $0{,}02L_R$ or 2 m for ice classes **1B** and **1C**. Where no clear forward borderline of the flat side of the hull is discernible, the aft boundary of the forward region is to be taken $0{,}4L_R$ aft of the forward perpendicular.

2.2.6 **Forefoot Region 1** is the area below the main ice belt zone extending from the stem, or the fore end of the bulb where a bulbous bow is fitted, to a position five frame spaces aft of the point of intersection between the level keel line and the raked stem.

2.2.7 **Forefoot Region 2** is the area below the main ice belt extending from the aft boundary of Forefoot Region 1 to the aft boundary of the forward region and encompasses both side and bottom shell plating.

2.2.8 The **Shoulder Region** is a part of the main ice belt zone in the forward region and extends from the aft boundary of the forward region to forward of the forward borderline of the flat side of the hull by a distance of 0,04L_R for ice classes **1AS** and **1A** or 0,02L_R for ice classes **1B** and **1C**. Where no clear forward borderline of the flat side of the hull is discernible, the forward boundary of the shoulder region is to be taken 0,32L_R aft of the forward perpendicular for ice classes **1AS** and **1A** or 0,36L_R aft of the forward perpendicular for ice classes **1B** and **1C**. The extent of the shoulder region forward of its aft boundary is not to be taken as less than 10 m for ice classes **1AS** and **1A** or 4 m for ice classes **1B** and **1C**.

2.2.9 The **Midship Region** extends from the aft boundary of the forward region to aft of the aft borderline of the flat side of the hull by a distance equal to the greater of 0,04L_R or 5 m for ice classes **1AS** and **1A** or the greater of 0,02L_R or 2 m for ice classes **1B** and **1C**. Where no clear aft borderline of the flat side of the hull is discernible, the aft boundary of the midship region is to be taken 0,2L_R forward of the aft perpendicular.

2.2.10 The **Aft Region** extends from the aft boundary of the midship region to the stern.

2.2.11 **Displacement** Δ is the displacement, in tonnes, at the Ice Deep Waterline when floating in water having a relative density of 1,0.

2.2.12 **Shaft power**, P_0, is the maximum propulsion shaft power, in kW, for which the machinery is to be classed.

2.3 Powering of ice strengthened ships

2.3.1 The total shaft power installed in ice strengthened ships is to be not less than P required by *Vol 3, Pt 1, Ch 1, 3 Machinery and engineering systems* for the desired Ice Class notation.

2.3.2 Ice strengthened ships which are to be considered to have an independent icebreaking capability are to be able to develop sufficient thrust to permit continuous mode icebreaking at a speed of at least five knots in ice having a thickness equal to the nominal value specified in *Vol 1, Pt 1, Ch 2, 3.10 Other notations 3.10.13* for the desired Ice Class and a snow cover of at least 0,3 m.

2.3.3 The requirements of *Vol 3, Pt 1, Ch 1, 2.4 Shell plating* are formulated on the assumption that the shaft power necessary to provide an independent icebreaking capability as described in *Vol 3, Pt 1, Ch 1, 2.3 Powering of ice strengthened ships 2.3.2* can be determined by the equation:

$$P_1 = 0{,}736 C_1 C_2 C_3 C_4 [240 B h (1 + h + 0{,}035 v^2) + 70 S_c \sqrt{L}]$$

where

B = breadth as defined in *Vol 1, Pt 3, Ch 1, 5 Definitions*

C_1 = $\dfrac{1{,}2B}{\sqrt[3]{\Delta}}$, but is not to be taken as less than 1,0

C_2 = 0,9 if the ship is fitted with a controllable pitch propeller, otherwise 1,0

C_3 = 0,9 if the rake of the stem is 45° or less, otherwise 1,0. The product $C_2 C_3$ is not to be taken as less than 0,85

C_4 = 1,1 if the ship is fitted with a bulbous bow, otherwise 1,0

h = ice thickness as defined in *Vol 3, Pt 1, Ch 1, 2.2 Definitions 2.2.2*

S_c = depth of snow cover

v = ship speed, in knots, when breaking ice of thickness h

2.3.4 The ice strengthening requirements of *Vol 3, Pt 1, Ch 1, 2.4 Shell plating* include a power-displacement correction factor, γ, which is to be determined as follows:

(a) Forward region

$$\gamma = 0{,}653 + 3{,}217\sqrt{P_0 \Delta} \times 10^{-5}$$

$$\text{or } \gamma = 0{,}876 + 9{,}908\sqrt{P_0 \Delta} \times 10^{-6}$$

$$\text{or } \gamma = 1{,}0 \text{ whichever is the least}$$

where P_0 and Δ are as defined in *Vol 3, Pt 1, Ch 1, 2.2 Definitions* .

For ships assigned ice classes **1AS** and **1A**, in which the installed shaft power P_0 exceeds the shaft power P_1 determined in accordance with *Vol 3, Pt 1, Ch 1, 2.3 Powering of ice strengthened ships 2.3.3* when the ship speed is taken as five knots, the ice thickness, *h*, as defined in *Vol 1, Pt 1, Ch 2, 3.10 Other notations 3.10.13* and the snow cover S_c is taken as 0,3 m, γ for the forward region is to be multiplied by the following factor:

(i) for shell plating

$$1 + 0{,}1\,\frac{P_0 - P_1}{P_1}$$

(ii) for framing, stringers and web frames

$$1 + 0{,}05\,\frac{P_0 - P_1}{P_1}$$

but γ need not be taken greater than 1,1.

(b) Midship and aft regions

$$\gamma = 0{,}653 + 9{,}908\sqrt{P_0 \Delta} \times 10^{-6}$$

$$\text{or } = 0{,}79\text{, whichever is the lesser.}$$

2.4 Shell plating

2.4.1 In way of the main ice belt zone, the thickness of the shell plating is not to be less than:

$$t = As\,\alpha_p\,\beta\,\gamma\sqrt{\frac{4{,}7}{\sigma_o}} + c \text{ mm}$$

where

c = corrosion-abrasion increment to be taken as 2 mm for first-year ice classes, *see also Vol 3, Pt 1, Ch 1, 2.4 Shell plating 2.4.3*

s = distance to the adjacent main or intermediate frame, in mm

A = 0,40 in association with transverse framing

= 0,41 in association with longitudinal framing

α_p = longitudinal distribution factor, dependent on Ice Class and longitudinal position, as given in *Table 1.2.2 Longitudinal distribution factor-shell plating*

β = vertical distribution factor, to be taken as 1,0 for all first-year ice classes

γ = power-displacement factor determined in accordance with *Vol 3, Pt 1, Ch 1, 2.3 Powering of ice strengthened ships 2.3.4*

σ_o = specified minimum yield stress of the steel, in N/mm^2. For mild steel the value 235 N/mm^2 is to be used.

Table 1.2.2 Longitudinal distribution factor-shell plating

Ice Class	α_p		
	Forward	Midship	Aft
1AS	1,00	0,95	0,85
1A	0,98	0,86	0,73
1B	0,93	0,71	0,57
1C	0,86	0,53	0,38

2.4.2 Where operation in first-year ice is an emergency feature as recognised by *Vol 1, Pt 1, Ch 2, 3.10 Other notations 3.10.13* with a * annotated to the Ice Class notation, consideration will be given to the use of fully plastic design criteria for the shell plating.

2.4.3 If a recognised low friction surface coating is to be applied in way of the main ice belt and is to be maintained in good condition during service, the thickness determined in accordance with *Vol 3, Pt 1, Ch 1, 2.4 Shell plating 2.4.1* may be reduced by 1 mm.

2.4.4 For ice classes **1AS** and **1A**, where the hull form includes a pronounced shoulder, the value of the corrosion-abrasion increment in the shoulder region will be specially considered.

2.4.5 For ice classes **1AS** and **1A**, the thickness of shell plating is to be as follows:

(a) In Forefoot Region 1 – not less than that determined in accordance with *Vol 3, Pt 1, Ch 1, 2.4 Shell plating 2.4.1* for the main ice belt zone in the forward region.
(b) In Forefoot Region 2 – 2 mm greater than that required by *Vol 1, Pt 6, Ch 3 Scantling Determination* or *Vol 1, Pt 7 Enhanced Structural Assessment (Provisional)* for ships with TLA notation.
(c) For the forward 0,2L_R, the region 2 m above the main ice belt zone in ships having an open water speed equal to and exceeding 17,5 knots (9 m/sec) – not less than that required in the ice belt in the Midship Region.

2.4.6 Changes in plating thicknesses in the longitudinal direction are to take place gradually. Side scuttles are not to be situated in the ice belt.

2.4.7 If the weather deck in any part of the ship is situated below the upper limit of the ice belt, as may be the case of a raised-quarter decker, the bulwark is to be reinforced to a standard required for the shell plating in the main ice belt.

2.5 Transverse framing

2.5.1 The increased requirements for transversely framed structures are normally met by the addition of intermediate frames.

2.5.2 Ships with shock enhanced notation transverse intermediate frames are not to be fitted. The ice strengthening requirements are to be met by the use of reduced main frame spacing.

2.5.3 The section modulus of transverse main and intermediate frames (including a width of attached plating equal to *s*), is to be determined in accordance with the following formula:

$$Z = Cs\,\alpha_t\,\beta\,\gamma^2\,\frac{4,7}{\sigma_o l}\,(3\,l^2 - h^2)\,K \text{ cm}^3$$

where

d = distance, in metres, measured along the frame from the lower span point to the ice deep waterline or from the upper span point to the ice light waterline, whichever is the lesser. In no case is this distance to be taken greater than $\frac{l}{2}$

h = nominal ice thickness, in metres, for the Ice Class as defined in *Vol 1, Pt 1, Ch 2, 3.10 Other notations 3.10.13*

s, β, γ and σ_o are as defined in *Vol 3, Pt 1, Ch 1, 2.4 Shell plating 2.4.1*

C = 12,5

K = $\frac{4d(l-d)}{l^2}$ but is not to be taken greater than 1,0 nor less than 0,3. If the lower span point is above the ice load waterline or the upper span point is below the ice light waterline, then k is to be taken as 0,3

α_t = longitudinal distribution factor, dependent on Ice Class and longitudinal position, as given in *Table 1.2.3 Longitudinal distribution factor - transverse framing*

l = span, in metres, measured along a chord at the side between the span points. For definitions of span points, *see Vol 1, Pt 6, Ch 2, 2 Structural design*. Where adjacent main and intermediate frames have different end connections, resulting in different spans, a mean value is to be used.

Table 1.2.3 Longitudinal distribution factor - transverse framing

Ice Class	α_t		
	Forward	Midship	Aft
1AS	1,00	0,87	0,66
1A	0,89	0,68	0,49
1B	0,78	0,49	0,33
1C	0,66	0,31	0,16

2.5.4 The inertia of transverse main and intermediate frames including a width of attached plating equal to s is to be determined in accordance with the following formula:

$$I = 4Z\,l \text{ cm}^4$$

where

Z and l are as defined in *Vol 3, Pt 1, Ch 1, 2.5 Transverse framing 2.5.3*.

2.5.5 The cross-sectional shear resisting area of transverse main and intermediate frames is to be determined in accordance with the following formula:

$$A = Cs\,\alpha_t\,\beta\,\gamma^2\,\frac{4,7}{\sigma_o}\,K_s \text{ cm}^2$$

where s, β, γ and σ_o are as defined in *Vol 3, Pt 1, Ch 1, 2.4 Shell plating 2.4.1*

C = 3,75

K_s = 0,5 if the upper span point is below the bottom edge of the main ice belt zone or the lower span point is above the upper edge of the main ice belt zone

= 1,0 for all other cases

α_t = is as defined in *Vol 3, Pt 1, Ch 1, 2.5 Transverse framing 2.5.3*.

2.5.6 Except as allowed by *Vol 3, Pt 1, Ch 1, 2.5 Transverse framing 2.5.7*, main and intermediate frames having scantlings as required by *Vol 3, Pt 1, Ch 1, 2.5 Transverse framing 2.5.2* are to be continued and bracketed to the first primary longitudinal member outside of the minimum extent of ice framing given in *Table 1.2.4 Minimum extent of ice framing* or to the top of floors in ships having a single bottom. In the latter case intermediate frames will require to be bracketed, or otherwise efficiently attached to a gusset plate which is to be fitted at the level of top of floors. The free edge of the horizontal gusset should be suitably supported. In this context a primary longitudinal member is defined as either a deck, inner bottom, margin plate, deep tank top or ice stringer complying with the requirements of *Vol 3, Pt 1, Ch 1, 2.8 Primary longitudinal members supporting transverse ice framing*.

Table 1.2.4 Minimum extent of ice framing

Ice Class	Region	Minimum extent of ice framing	
		Above Ice Deep Waterline (mm)	Below Ice Light Waterline (mm)
1AS	Forward (stem to 0,3L_R)	1200	To double bottom or top of floors or 1600 mm, whichever is the greater
	Forward (abaft 0,3L_R) and Midship	1200	1600
	Aft	1200	1200
1A, 1B, 1C	Forward (stem to 0,3L_R)	1000	1600
	Forward (abaft 0,3L_R) and Midship	1000	1300
	Aft	1000	1000

2.5.7 If a primary longitudinal member is fitted within 0,25 m inside a boundary of the minimum extent of ice framing, intermediate frames may be terminated at that member.

2.5.8 If a primary longitudinal member is fitted within 1 m inside a boundary of the minimum extent of ice framing, the intermediate frames may be terminated at that boundary, provided that their ends are attached to the adjacent main frames by a horizontal intercostal member having the same scantlings as the intermediate frames.

2.5.9 If primary longitudinal members are not fitted, or are located more than 1 m inside a boundary of the minimum extent of ice framing, then the intermediate frames may be either:

(a) extended to a primary longitudinal member or equivalent as defined by *Vol 3, Pt 1, Ch 1, 2.5 Transverse framing 2.5.6*.
(b) terminated at the boundary of minimum extent of ice framing and attached by a horizontal intercostal member, having the same scantlings as the intermediate frames, to the adjacent main frames. The scantlings of the main frames are to be based on the spacing and span of the main frames. The inertia of the intermediate frames is to be not less than 75 per cent of the main frames.

2.5.10 Except where provided for in *Vol 3, Pt 1, Ch 1, 2.5 Transverse framing 2.5.7* and *Vol 3, Pt 1, Ch 1, 2.5 Transverse framing 2.5.9*, the ends of intermediate frames are to be bracketed or otherwise efficiently attached to a primary longitudinal member or are to be attached to adjacent brackets, floors or main frames by a longitudinal flat bar. *see also Vol 3, Pt 1, Ch 1, 2.7 Framing - General requirements 2.7.5*.

2.5.11 In twin screw ships, three intermediate frames forward of, and three aft of, the propeller blade tips are to extend to the double bottom.

2.6 Longitudinal framing

2.6.1 The section modulus of longitudinal frames (including a width of attached plating equal to *s*), is to be determined in accordance with the following formula:

$$Z = Cs\,\alpha_l\,\beta\,\gamma^2\,l^2\,\frac{4,7}{\sigma_o}\ \text{cm}^3$$

where

h = ice thickness as defined in *Vol 3, Pt 1, Ch 1, 2.2 Definitions 2.2.2*

where

l = is as defined in *Vol 3, Pt 1, Ch 1, 2.5 Transverse framing 2.5.3*

s = spacing, in mm, of longitudinal frames but need not be taken as greater than 1000h

C = 16,6

α_l = longitudinal distribution factor, dependent on Ice Class and longitudinal position, as given in *Table 1.2.5 Longitudinal distribution factor-longitudinal framing*

β, γ and σ_o are as defined in *Vol 3, Pt 1, Ch 1, 2.4 Shell plating 2.4.1*.

Table 1.2.5 Longitudinal distribution factor-longitudinal framing

Ice Class	α_1		
	Forward	Midship	Aft
1AS	1,00	0,95	0,71
1A	0,90	0,74	0,53
1B	0,80	0,51	0,34
1C	0,68	0,32	0,16

2.6.2 The inertia of longitudinal frames, including a width of attached plating equal to s, is to be determined in accordance with the following formula:

$$I = Cs\,\alpha_l\,\beta\,\gamma^2\,l^{2,3}\,\frac{4,7}{\sigma_o}\ \text{cm}^4$$

where

C = 270

Other symbols are as defined in *Vol 3, Pt 1, Ch 1, 2.6 Longitudinal framing 2.6.1*.

2.6.3 The cross-sectional shear resisting area of longitudinal frames is to be determined in accordance with the following formula:

$$A = Fs\,\alpha_l\,\beta\,\gamma^2\,l\,\frac{4,7}{\sigma_o}\ \text{cm}^2$$

where

F = 2,5

Other symbols are as defined in *Vol 3, Pt 1, Ch 1, 2.6 Longitudinal framing 2.6.1*.

2.6.4 Where longitudinal framing is adopted, frames satisfying the requirements of *Vol 3, Pt 1, Ch 1, 2.6 Longitudinal framing 2.6.1* to *Vol 3, Pt 1, Ch 1, 2.6 Longitudinal framing 2.6.3* are to be fitted within the minimum vertical extent of ice framing in *Table 1.2.4 Minimum extent of ice framing*.

2.7 Framing - General requirements

2.7.1 The web thickness of ice frames is not, in general, to be less than half that of the attached shell plating with a minimum of 9 mm.

2.7.2 Where a frame intersects a boundary between two of the hull regions defined in *Vol 3, Pt 1, Ch 1, 2.2 Definitions* , the scantling requirements applicable will be those for the forward region if the forward midship boundary is intersected or for the midship region if the aft midship boundary is intersected.

2.7.3 Main and intermediate frames within the minimum extent of ice framing given in *Table 1.2.4 Minimum extent of ice framing* are to be efficiently supported to prevent tripping, e.g. as shown in *Figure 1.2.2 Framing support*. The distance between anti-tripping supports is not to exceed 1500 mm. The extent of anti-tripping supports is to be as given in *Table 1.2.6 Extent of anti-tripping supports*.

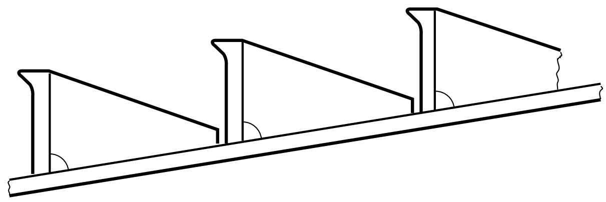


Figure 1.2.2 Framing support

Table 1.2.6 Extent of anti-tripping supports

Ice Class	Extent of anti-tripping supports
1AS	All regions
1A	Forward and midship region
1B	Forward region
1C	Forward region

2.7.4 Ice frames are to be attached to the shell plating by double continuous welding and are not to be scalloped except at shell plating seams or butts. However, in the case of the aft region for Ice Class **1A**, **1B** and **1C** and the midship region for Ice Class **1B** and **1C**, consideration will be given to the use of intermittent welding provided the requirements of *Vol 1, Pt 6, Ch 6, 4.9 Intermittent and single sided fillet welding* are complied with.

2.7.5 Frames are to be effectively attached to supporting structure by brackets. In general, longitudinals are to be connected to both sides of cut-outs in the webs of transverse structure.

2.7.6 The effective weld area attaching ice frames to primary members is not to be less than the shear area for the frames as required by *Vol 3, Pt 1, Ch 1, 2.5 Transverse framing 2.5.2* or *Vol 3, Pt 1, Ch 1, 2.6 Longitudinal framing 2.6.3*, as appropriate.

2.7.7 Where a bulkhead or deck is fitted instead of an ice strengthened frame, the thickness of the bulkhead or deck adjacent to the shell is normally to be that of the frame for a width sufficient to give an area equal to the frame.

2.8 Primary longitudinal members supporting transverse ice framing

2.8.1 The section modulus of ice stringers or of decks adjacent to hatchways, including a width of attached plating determined in accordance with *Vol 1, Pt 6, Ch 2, 2.3 Section properties* and taken about an axis parallel to the plating, is to be determined in accordance with the following formula:

$$Z = C\,\alpha_o\,\beta\,\gamma^2\,l^2\,\frac{4,7}{\sigma_o}\ \text{cm}^3$$

where

l = span, in metres, of the ice stringer or deck adjacent to a hatchway determined in accordance with *Vol 1, Pt 6, Ch 2, 2 Structural design*.

C = 11 300

α_o = longitudinal distribution factor, dependent on Ice class and longitudinal position, as given in *Table 1.2.7 Longitudinal distribution factor-primary longitudinal members*

β, γ and σ_o are as defined in *Vol 3, Pt 1, Ch 1, 2.4 Shell plating 2.4.1*.

Table 1.2.7 Longitudinal distribution factor-primary longitudinal members

Ice Class	α_o		
	Forward	Midship	Aft
1AS	1,00	0,98	0,89
1A	0,87	0,75	0,64
1B	0,78	0,64	0,51
1C	0,68	0,53	0,37

2.8.2 The cross-sectional shear resisting area of ice stringers or of decks adjacent to hatchways is to be determined in accordance with the following formula:

$$A = C\,\alpha_o\,\beta\,\gamma^2\,l\,\frac{4,7}{\sigma_o}\ \text{cm}^2$$

where

C = 1240

Other symbols are as defined in *Vol 3, Pt 1, Ch 1, 2.8 Primary longitudinal members supporting transverse ice framing 2.8.1*.

2.8.3 Where the span of a deck adjacent to a hatchway exceeds 10 times the width of the deck strip the scantlings of the deck section may require special consideration to ensure adequate stiffness.

2.8.4 The webs of primary longitudinal members supporting transverse ice frames are to be stiffened and connected to the main or intermediate frames so that the distance, *r*, between such stiffening is not to be greater than given according to the following formula:

$$r = \frac{291t^3}{\alpha_0\,\beta\,\gamma^2}\ \text{mm}$$

where

t = thickness, in mm, of the primary longitudinal member adjacent to the shell plating

Other symbols are as defined in *Vol 3, Pt 1, Ch 1, 2.8 Primary longitudinal members supporting transverse ice framing 2.8.1*.

2.8.5 The minimum thickness of the web plating of longitudinal primary members is to comply with the requirements of *Vol 1, Pt 6, Ch 6, 5 Construction details*.

2.9 Web frames

2.9.1 The section modulus of web frames supporting ice stringers or longitudinal ice frames including a width of attached plating determined in accordance with *Vol 1, Pt 6, Ch 2, 2 Structural design* and taken about an axis parallel to the plating is to be determined in accordance with the following formula:

$$Z = Cs\,\alpha_o\,\beta\,\gamma^2\,l\,\frac{4,7}{\sigma_o}\ \text{cm}^3$$

where

l = span, in metres, of the web frames determined in accordance with *Vol 1, Pt 6, Ch 2, 2 Structural design*

s = spacing of web frames, in metres

C = 20 600

α_o = longitudinal distribution factor as given in *Table 1.2.7 Longitudinal distribution factor-primary longitudinal members*

β, γ and σ_o are as defined in *Vol 3, Pt 1, Ch 1, 2.4 Shell plating 2.4.1*.

2.9.2 The cross-sectional shear resisting area of web frames supporting ice stringers or longitudinal ice frames is to be determined in accordance with the following formula:

$$A = C\,\alpha_o\,\beta\,\gamma^2\,s\,\frac{4,7}{\sigma_o}\ \text{cm}^2$$

where

C = 1240

α_o and s are as defined in *Vol 3, Pt 1, Ch 1, 2.9 Web frames 2.9.1*

β, γ and σ_o are as defined in *Vol 3, Pt 1, Ch 1, 2.4 Shell plating 2.4.1*.

2.9.3 Ice stringers are to be bracketed or otherwise efficiently attached to the web frames or transverse bulkheads.

2.9.4 The thickness of the web is generally not to be less than one per cent of the web depth.

2.10 Stem

2.10.1 The stem is to be made of rolled, cast or forged steel or of shaped steel plates. A sharp edged stem, as shown in *Figure 1.2.3 A sharp edged stem* improves the manoeuvrability of the ship in ice.

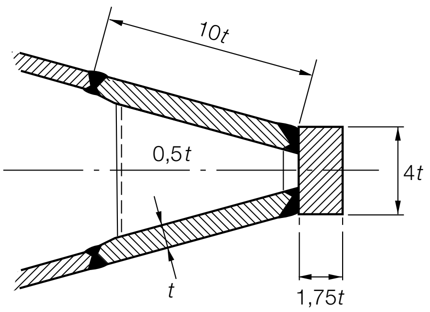


Figure 1.2.3 A sharp edged stem

2.10.2 The section modulus of the stem in the fore and aft direction is not to be less than determined in accordance with the following formula:

$$Z = 1500\left(\alpha_o\,\beta\,\gamma^2\right)^{\frac{3}{2}}\ \text{cm}^3$$

where

α_o = longitudinal distribution factor for the forward region as given in *Table 1.2.3 Longitudinal distribution factor - transverse framing*

β and γ are as defined in *Vol 3, Pt 1, Ch 1, 2.4 Shell plating 2.4.1*.

2.10.3 The dimensions of a welded stem constructed as shown in *Figure 1.2.3 A sharp edged stem* are to be determined in accordance with the following formula:

$$t = 31\sqrt{\alpha_o\,\beta\,\gamma^2}\ \text{mm}$$

where

t = thickness of the side plates, in mm.

2.10.4 The plate thickness, t, of a shaped plate stem or a bulbous bow is to be determined in accordance with the following formula:

$$t = As\,\alpha_p\,\beta\,\gamma\sqrt{\frac{4,7}{\sigma_o}} + 2 \text{ mm}$$

where

s = the distance, in mm, between horizontal webs diaphragm plates having a thickness of at least 0,5t mm

A = 0,50

α_p, β, γ and σ_o are as defined in *Vol 3, Pt 1, Ch 1, 2.4 Shell plating 2.4.1*.

2.10.5 The reinforced stem is to extend from the keel plate to 750 mm above the ice load waterline and is to be internally strengthened by floors, brackets or webs having a thickness of at least 0,5t and spaced not more than 600 mm apart.

2.10.6 In bulbous bow constructions the extent of plating having the thickness, t, as specified in *Vol 3, Pt 1, Ch 1, 2.10 Stem 2.10.4*, below the ice light waterline should be such as to cover that part of the bulb forward of the vertical line originating at the intersection of the ice light waterline and the stem contour at the centreline. A suitably tapered transition piece should be arranged between the reinforced stem plating and keel. However, in no case should the reinforced stem plating extend vertically below the Ice Light Waterline for less than 750 mm. The adjacent strake to the reinforced shaped stem plating of the bulb should be in accordance with the requirements of *Vol 3, Pt 1, Ch 1, 2.4 Shell plating 2.4.1*.

2.10.7 Where in the ice belt region the radius of the stem or bulb front plating is large, one or more vertical stiffeners are to be fitted in order to meet the section modulus requirement of *Vol 3, Pt 1, Ch 1, 2.10 Stem 2.10.2*. In addition, vertical ring stiffening will be required for the bulb.

2.10.8 The dimensions of the stem may be tapered to the requirements of *Vol 1, Pt 6, Ch 3, 5.2 Plate keel* at the upper deck. The connections of the shell plating to the stem are to be flush.

2.10.9 For towing purposes, a mooring pipe with an opening not less than 250 mm by 300 mm having inner surfaces at least 150 mm wide with a rounding radius of not less than 100 mm is to be fitted in the bow bulwark on the centreline. A bitt, or other convenient means of securing the line, is to be dimensioned to withstand the breaking strength of the ship's towline.

2.11 Stern

2.11.1 Where the screwshaft diameter exceeds the Rule diameter, the propeller post is to be correspondingly strengthened. *see Vol 1, Pt 3, Ch 3, 2 Rudders*.

2.11.2 A transom stern is not normally to extend below the ice load waterline. Where this cannot be avoided, the transom is to be kept as narrow as possible and the scantlings of plating and stiffeners are to be as required for the midship region.

2.12 Bossings and shaft struts

2.12.1 Shaftings and sterntubes of ships with two or more propellers are generally to be enclosed within plated bossings. If detached supporting struts are necessary, their design, strengthening and attachment to the hull will be specially considered.

2.13 Rudder and steering arrangements

2.13.1 Rudder posts, rudder horns, solepieces, rudder stocks and pintles are to be dimensioned in accordance with *Vol 1, Pt 3, Ch 3, 2 Rudders* and *Vol 1, Pt 3, Ch 3, 2.13 Rudder bending moment, MR* as appropriate. Rudder scantlings are to be determined in accordance with *Vol 1, Pt 3, Ch 3, 2 Rudders* using the basic stock diameter, δ_s. The speed used in the calculations is to be the service speed or that given in *Table 1.2.8 Minimum speeds*, whichever is the greater. When used in association with the speed given in *Table 1.2.8 Minimum speeds*, the hull form factor and rudder profile coefficients are to be taken as 1,0.

Table 1.2.8 Minimum speeds

Ice Class	Minimum speed, in knots
1AS	20
1A	18
1B	16
1C	14

2.13.2 For double plate rudders, the minimum thickness of plating and horizontal and vertical webs in the main ice belt zone is to be determined as for shell plating in the aft region in accordance with *Vol 3, Pt 1, Ch 1, 2.4 Shell plating 2.4.1*. For the horizontal and vertical webs the corrosion-abrasion increment, *c*, need not be added.

2.13.3 For ice classes **1AS** and **1A**, the rudder head and the upper edge of the rudder are to be protected against ice pressure by an ice knife, or equivalent.

2.13.4 Due regard is to be paid to the method of securing the rudder in the centreline position when backing into ice. Where possible, rudder stoppers working on the blade or rudder head are to be fitted.

2.13.5 Where an ice class notation is included in the class of a ship, the nozzle construction requirements as defined in *Vol 1, Pt 3, Ch 3, 5 Fixed and steering nozzles, bow and stern thrust units, ducted propellers* are to be upgraded to include abrasion allowance as follows:

Ice Class	Thickness increment
1AS	5 mm
1A	4 mm
1B	3 mm
1C	2 mm

However, the thickness of the shroud plating is not to be less than the shell plating for the aft region as obtained from *Vol 3, Pt 1, Ch 1, 2.4 Shell plating 2.4.1* taking frame spacing *s* in the formula as 500 mm.

2.13.6 The scantlings of the stock, pintles, gudgeon and solepiece associated with the nozzle are to be increased on the basis given in *Vol 3, Pt 1, Ch 1, 2.13 Rudder and steering arrangements 2.13.1*. However, the diameter of the nozzle stock is to be not less than that calculated in the astern condition taking the astern speed as half the speed given in *Table 1.2.8 Minimum speeds* or the actual astern speed, whichever is the greater.

2.13.7 Nozzles with articulated flaps will be subject to special consideration.

2.14 Direct calculations

2.14.1 If, as an alternative to the requirements of *Vol 3, Pt 1, Ch 1, 2.8 Primary longitudinal members supporting transverse ice framing* and *Vol 3, Pt 1, Ch 1, 2.9 Web frames*, the scantlings of primary longitudinal members and web frames are determined by direct calculation, as permitted by *Vol 1, Pt 3, Ch 1, 2 Direct calculations*, then:

(a) the applied ice load may be taken as $775\alpha_o \beta \gamma^2$ kN per metre of ship length evenly distributed over a depth equal to the nominal ice thickness, *h*, for the Ice Class;

(b) the scantlings are to be suitable for the centre of the load depth to be located at any height between the ice load waterline and the ice light waterline;

(c) the scantlings determined in association with *Vol 3, Pt 1, Ch 1, 2.14 Direct calculations 2.14.1* and *Vol 3, Pt 1, Ch 1, 2.14 Direct calculations 2.14.1* are to be sufficient to ensure that the von Mises-Hencky combined stress does not exceed 90 per cent of the yield stress of the steel.

■ *Section 3* Machinery and engineering systems

3.1 General

3.1.1 Where the notation, Ice Class **1AS**, **1A**, **1B** or **1C** is desired, the requirements of this Section, in addition to those for open water service, are to be complied with so far as they are applicable.

3.1.2 This Section is to be read in conjunction with the requirements for Machinery and Engineering Systems in *Vol 2, Pt 1, Ch 1 General Requirements for Classification of Engineering Systems* and *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*.

3.2 Symbols and definitions

3.2.1 The symbols used in this Section are defined as follows:

A_{WF} = area of the waterline of the bow, in m^2, as shown in *Figure 1.3.1 Definition of angles, areas and length*

B = moulded breadth of ship, in metres

D_P = diameter of the propeller, in metres

H_M = thickness of the brash ice in mid channel, in metres

H_F = thickness of the brash layer displaced by the bow, in metres

L_{BOW} = length of bow, in metres, as shown in *Figure 1.3.1 Definition of angles, areas and length*

L_{PAR} = length of parallel middle body, in metres, as shown in *Figure 1.3.1 Definition of angles, areas and length*

L_{WL} = length of ship at deep draught waterline, in metres

T_{ICE} = maximum ice class draught amidships, in metres, corresponding to the deep draught waterline

Δ = displacement, in tonnes, on the maximum Ice Class draught amidships on the deep draught waterline, *see Vol 3, Pt 1, Ch 1, 2.2 Definitions 2.2.1*. This displacement need not be taken as greater than 80 000 tonnes

α = the angle of the waterline at B/4, *see Figure 1.3.1 Definition of angles, areas and length*

φ_1 = the rake of the stem at the centreline, as shown in *Figure 1.3.1 Definition of angles, areas and length*

φ_2 = the rake of the bow at B/4, as shown in *Figure 1.3.1 Definition of angles, areas and length*.

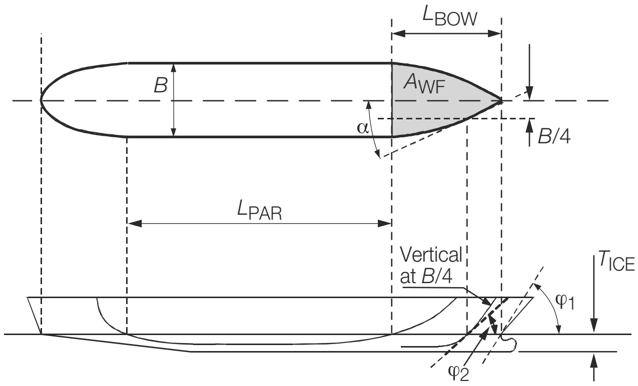


Figure 1.3.1 Definition of angles, areas and length

3.3 Engine output

3.3.1 **Definition**. The total engine output, P in *Vol 3, Pt 1, Ch 1, 3.3 Engine output 3.3.2*, is the maximum output the propulsion machinery can continuously deliver to the propulsion system with the propeller(s) operating at the revolutions per minute at the maximum torque for which the system is to be classed. If the output of the machinery is restricted by technical means or by any Regulations applicable to the ship, P, shall be taken as the restricted output.

3.3.2 Required engine output:

(a) For **Ice Class 1AS** and **1A**, the total engine output is not to be less than determined by the following formula:

$$P = K_E \frac{\left(\frac{R_{CH}}{1000}\right)^{\frac{3}{2}}}{D_p} \text{ kW}$$

where K_E is as shown in *Table 1.3.1 Coefficient of propulsion, K_E*

R_{CH}, in N, is the resistance of the ship in a channel with brash ice and a consolidated layer, using the following equation:

$$R_{CH} = C_1 + C_2 + 845 (H_F + H_M)^2 \left(B + 1,85H_F - \frac{2H_F}{\tan \Psi}\right) \bullet$$

$$(0,15 \cos \varphi_2 + \sin\psi \bullet \sin\alpha) + 42L_{PAR} H_F^2 + 825K_d \frac{A_{wf}}{L_{WL}}$$

where

$$Kd = \left[\frac{L_{WL}T_{ICE}}{B^2}\right]^3$$

but is not to be taken as more than 20 or less than 5

$$H_F = 0,26 + \sqrt{(H_M B)}$$

H_M = 1,0 for **Ice Classes 1A** and **1AS**

C_1 and C_2 take into account a consolidated upper layer of the brash ice and can be taken as zero for **Ice Class 1A**. For **Ice Class 1AS**:

$$C_1 = 23 \frac{BL_{PAR}}{\frac{2T_{ICE}}{B} + 1} + (1 + 0,021 \; 4_1)(45,8B + 14,7L_{BOW} + 29BL_{BOW})$$

$$C_2 = (1 + 0,063 \; \varphi_1)(1530 + 170B) + (400 + 480 \frac{T_{ICE}}{B}) \frac{B^2}{\sqrt{L_{WL}}}$$

$$\Psi = \arctan\left[\frac{\tan \varphi_2}{\sin \alpha}\right]$$

(b) For **Ice Class 1B** and **1C**, the total engine output is not to be less than that determined by the following formula and in no case less than 740 kW:

$$P = f_1 f_2 f_3 (f_4 \Delta + P_o) \text{ kW}$$

where

f_1 = 1,0 for a fixed pitch propeller

= 0,9 for a controllable pitch propeller

$f_2 = \frac{\varphi_1}{200} + 0,675$ but not more than 1,1

f_2 = 1,1 for a bulbous bow

The product, $f_1 f_2$, is not to be taken as less than 0,85.

$f_3 = \frac{1,2B}{\Delta^{1/3}}$ but not less than 1,0

f_4 and P_0 are to be taken as shown in *Table 1.3.2 Values of f_4 and P_0* :

Δ is as defined in *Vol 3, Pt 1, Ch 1, 3.2 Symbols and definitions*.

Table 1.3.1 Coefficient of propulsion, K_E

No. of propellers	Propeller type	
	Controllable pitch propeller	Fixed pitch propeller
1	2,03	2,26
2	1,44	1,60
3	1,18	1,31

Table 1.3.2 Values of f_4 and P_0

	1B	1C	1B	1C
	Δ < 30 000 *t*		Δ ≥ 30,000 *t*	
f_4	0,22	0,18	0,13	0,11
P_0	370	0	3070	2100

3.4 Materials for shafting

3.4.1 All components of the main propulsion system are to be of steel or other approved ductile material.

3.4.2 For screwshafts in ships intended for the notation **Ice Class 1AS or 1A** and where the connection between the propeller and the screwshaft is by means of a key, Charpy impact tests are to be made in accordance with the requirements of *Ch 5, 3.4 Mechanical tests 3.4.12*.

3.5 Materials for propellers

3.5.1 Propellers and propeller blades are to be of cast steel or copper alloys.

3.5.2 For steel propellers, the elongation of the material used is to be not less than 19 per cent for a test piece length of 5*d*. Charpy impact tests are to be carried out in accordance with the requirements of *Rules for the Manufacture, Testing and Certification of Materials, July 2015*.

3.5.3 Spheroidal cast iron load transmitting components of controllable-pitch mechanisms are to be manufactured, tested and certified in accordance with the requirements of *Table 7.3.5 Mechanical properties: special qualities* in Ch 7,3 of the Rules for Materials.

3.6 Determination of ice torque

3.6.1 Dimensions of propellers, shafting and gearing are determined by formulae taking into account the impact when a propeller blade hits ice. The ensuing load is hereinafter defined by ice torque, *M*.

$$M = m D^2 \text{ kN m}$$

where

m = 21,10 for **Ice Class 1AS**

= 15,69 for **Ice Class 1A**

= 13,04 for **Ice Class 1B**

= 11,96 for **Ice Class 1C**

D = diameter of propeller, in metres.

3.6.2 If the propeller is not fully submerged when the ship is in ballast condition, the ice torque for **Ice Class 1A** is to be used for **Ice Classes 1B** and **1C**.

3.7 Propeller blade sections

3.7.1 The width, *L*, and thickness, *T*, of propeller blade sections are to be determined so that:

(a) at the radius 0,25*D*/2, for solid propellers

$$LT^2 \geq \frac{26\,478\,000}{\sigma_u\left(0,65 + 0,7p_r/D\right)}\left(27,2\frac{P}{NR} + 2,24M\right)$$

(b) at radius 0,35*D*/2 for controllable pitch propellers

$$LT^2 \geq \frac{21\,084\,300}{\sigma_u\left(0,65 + 0,7p_r/D\right)}\left(27,2\frac{P}{NR} + 2,35M\right)$$

(c) at the radius 0,6*D*/2

$$LT^2 \geq \frac{9\,316\,320}{\sigma_u\left(0,65 + 0,7p_r/D\right)}\left(27,2\frac{P}{NR} + 2,86M\right)$$

where

D = diameter of propeller, in metres

L = length of the expanded cylindrical section of the blade, at the radius in question, in mm

M = ice torque as defined in *Vol 3, Pt 1, Ch 1, 3.6 Determination of ice torque 3.6.1*

N = number of blades

P_r = propeller pitch at the radius in question, for solid propellers, in metres

= 0,7 nominal pitch for controllable pitch propellers, in metres

P = shaft power as defined in *Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications*

R = propeller speed, in rev/min

T = the corresponding maximum blade thickness, in mm

σ_u = specified minimum tensile strength of the blade material, in N/mm^2.

3.7.2 Where the blade thickness derived from these formulae is less than the blade thickness derived by *Vol 2, Pt 4, Ch 1 Propellers*, the latter is to apply.

3.8 Propeller blade minimum tip thickness

3.8.1 The blade tip thickness, *t*, at the radius *D*/2 is to be determined by the following formulae:

Ice Class 1AS

$$t = (20 + 2D)\sqrt{\frac{490}{\sigma_u}}\ \text{mm}$$

Ice Classes 1A, **1B** and **1C**

$$t = (15 + 2D)\sqrt{\frac{490}{\sigma_u}}\ \text{mm}$$

where D and σ_u are as defined in *Vol 3, Pt 1, Ch 1, 3.6 Determination of ice torque* and *Vol 3, Pt 1, Ch 1, 3.7 Propeller blade sections* respectively.

3.9 Intermediate blade sections

3.9.1 The thickness of other sections is to conform to a smooth curve connecting the section thicknesses as determined by *Vol 3, Pt 1, Ch 1, 3.7 Propeller blade sections* and *Vol 3, Pt 1, Ch 1, 3.8 Propeller blade minimum tip thickness*.

3.10 Blade edge thickness

3.10.1 The thickness of blade edges is to be not less than 50 per cent of the derived tip thickness, t, measured at 1,25t from edge. For controllable pitch propellers this applies only to the leading edge.

3.11 Mechanisms for controllable pitch propellers

3.11.1 The strength of mechanisms in the boss of a controllable pitch propeller is to be 1,5 times that of the blade when a load is applied at the radius 0,9D/2 in the weakest direction of the blade.

3.12 Keyless propellers

3.12.1 When it is proposed to use keyless propellers, the fit of the propeller boss to the screwshaft will be specially considered.

3.13 Screwshafts

3.13.1 The diameter d_s at the aft bearing of the screwshaft fitted in conjunction with a solid propeller is to be not less than:

$$d_s = 1{,}08\sqrt[3]{\frac{\sigma_u L T^2}{\sigma_o}} \text{ mm}$$

where

L and T = proposed width and thickness respectively of the propeller blade section at 0,25D/2, in mm

σ_o = specified minimum yield stress of the material of the screwshaft, in N/mm^2

σ_u = specified minimum tensile strength of the blade material, in N/mm^2.

3.13.2 The diameter, d_s at the aft bearing of the screwshaft fitted in conjunction with a controllable pitch propeller is to be not less than:

$$d_s = 1{,}15\sqrt[3]{\frac{\sigma_u L T^2}{\sigma_o}} \text{ mm}$$

where

L and T = proposed width and thickness respectively of the propeller blade section at 0,35D/2, in mm.

3.13.3 Where the screwshaft diameter as derived by *Vol 3, Pt 1, Ch 1, 3.13 Screwshafts 3.13.1* or *Vol 3, Pt 1, Ch 1, 3.13 Screwshafts 3.13.2* is less than the diameter derived by *Vol 2, Pt 3, Ch 2, 4.4 Screwshafts and tube shafts 4.4.3* or *Vol 2, Pt 3, Ch 2, 4.4 Screwshafts and tube shafts 4.4.7* as applicable the latter is to apply.

3.13.4 The shaft may be tapered at the forward end in accordance with *Vol 2, Pt 3, Ch 2, 4.4 Screwshafts and tube shafts 4.4.5* or *Vol 2, Pt 3, Ch 2, 4.4 Screwshafts and tube shafts 4.4.6* as applicable.

3.14 Intermediate and thrust shafts

3.14.1 The diameters of intermediate shafts and thrust shafts in external bearings are to comply with *Vol 2, Pt 3, Ch 2, 4.2 Intermediate shafts 4.2.1* and *Vol 2, Pt 3, Ch 2, 4.3 Thrust shafts external to engines 4.3.1* respectively, except for **Ice Class 1AS** ice strengthening where these diameters are to be increased by 10 per cent.

3.15 Reduction gearing

3.15.1 Where gearing is fitted between the engine and the propeller shafting, the gearing is to be in accordance with *Vol 2, Pt 3, Ch 1 Gearing*, and is to be designed to transmit a torque, Y_i, determined by the following formula:

$$Y_i = Y + \frac{M I_h u^2}{I_1 + I_h u^2} \text{ kN m}$$

where

u = gear ratio = $\frac{\text{pinion speed}}{\text{wheel speed}}$

I_h = mass moment of inertia of machinery components rotating at higher speed

I_l = mass moment of inertia of machinery components rotating at lower speed, including propeller with an addition of 30 per cent of entrained water

(I_h and I_l are to be expressed in the same units)

M = ice torque as defined in *Vol 3, Pt 1, Ch 1, 3.6 Determination of ice torque*

Y = $9{,}55 \frac{P}{R}$.

P and *R* are as defined in *Vol 2, Pt 1, Ch 3, 3.3 Calculations and specifications*.

3.16 Starting arrangements

3.16.1 In addition to complying with the requirements of *Vol 2, Pt 7, Ch 3, 12.11 Dead ship condition starting arrangements*, *12.1*, *Vol 2, Pt 7, Ch 3, 12.12 Air receivers*, *Vol 2, Pt 2, Ch 1, 8.3 Starting air pipe systems and safety fittings* and *Vol 2, Pt 2, Ch 1, 7.2 Electrical starting arrangements* where applicable, the capacity of the air compressors is to be sufficient for charging the air receivers from atmospheric to full pressure in half an hour for a ship with **Ice Class 1AS** where the propulsion engine has to be reversed for going astern.

3.17 Sea inlet chests and cooling water systems

3.17.1 The cooling water system is to be designed to ensure a supply of cooling water when navigating in ice. For this purpose at least one cooling water inlet chest is to be arranged as follows:

(a) The sea inlet chest is to be situated near the centreline of the ship and well aft if possible.
(b) As guidance for design the volume of the chest shall be about one cubic metre for every 750 kW engine output of the ship including the output of auxiliary engines necessary for the ship's service.
(c) The chest shall be of sufficient height to allow ice to accumulate above the inlet pipe.
(d) A recirculating connection from the cooling water overboard discharge line, capable of full capacity discharge, is to be led to the chest.
(e) The net area through the grating at the shell opening is to be not less than four times the sectional area of the inlet pipe.

Where there are difficulties in meeting the requirements of *Vol 3, Pt 1, Ch 1, 3.17 Sea inlet chests and cooling water systems 3.17.1* and *Vol 3, Pt 1, Ch 1, 3.17 Sea inlet chests and cooling water systems 3.17.1* two smaller chests may be arranged for alternating intake and discharge of cooling water. The arrangement and situation otherwise shall be as above.

3.17.2 Heating coils may be installed in the upper part of the chest or chests.

3.17.3 Arrangements for circulating water from ballast tanks for cooling purposes may be useful as a reserve in ballast conditions but cannot be accepted as a substitute for sea inlet chests as described in *Vol 3, Pt 1, Ch 1, 3.17 Sea inlet chests and cooling water systems 3.17.1*.

3.18 Fire pumps in motor ships

3.18.1 In motor ships where clearing steam is not available, fire pumps are to be provided with suctions from the cooling water inlet chest referred to in *Vol 3, Pt 1, Ch 1, 3.17 Sea inlet chests and cooling water systems*.

Section 1 General requirements

1.1 Application

1.1.1 This Chapter is to be read in conjunction with the requirements for Machinery and Engineering Systems in *Vol 2, Pt 1, Ch 1 General Requirements for Classification of Engineering Systems* and *Vol 2, Pt 1, Ch 3 Requirements for Design, Construction, Installation and Sea Trials of Engineering Systems*.

1.1.2 The requirements of this Chapter are in addition to other relevant Chapters in the Rules for main and auxiliary machinery.

1.1.3 The Rules contained in this Chapter cover machinery arrangements and control systems necessary for operating Mobility and/or Ship Type machinery from a (centralised) control station on the bridge under normal sea-going and manoeuvring conditions, but do not signify that the machinery space may be operated unattended.

1.1.4 In general, ships complying with the requirements of this Chapter will be eligible for the machinery class notation **IP**, *see Vol 1, Pt 1, Ch 2, 3.9 Machinery and Engineering Systems notations 3.9.2*.

1.1.5 The details of control systems will vary with the type of machinery being controlled, and special consideration will be given to each case.

1.2 Documentation required for design review

1.2.1 **Control systems.** Where control systems are applied to Mobility and/or Ship Type machinery or equipment, the following plans are to be submitted in triplicate:

- Details of operating medium, i.e. pneumatic, hydraulic or electric including standby sources of power.
- Description of operation with explanatory diagrams.
- Line diagrams of control circuits.
- List of monitored points.
- List of control points.
- List of alarm points.
- Test schedule including test facilities provided.

1.2.2 Plans for the control systems of the following machinery are to be submitted:

- Main propelling machinery, including all auxiliaries for propulsion systems.
- Controllable pitch propellers.
- Electric generating plant.
- Evaporating and distilling systems for use with main steam machinery.
- Steam raising plant for Mobility and/or Ship Type systems.

1.2.3 **System Operational Concept.** A System Operational Concept document covering the Power and Propulsion system, including a description of how the control, alarm and safety systems for the integrated propulsion system provide effective means for operation and control during all ship operational conditions.

1.2.4 **Alarm systems**. Details of the overall alarm system linking the machinery space control station with the bridge control station are to be submitted including details of alerts to be presented by the user interface, with:

(a) an approach to alert category assignments which is in accordance with the IMO *Code on Alerts and Indicators, 2009*; and
(b) for alarms required by these Rules the intended operator response and the message to be presented.

1.2.5 **Control stations**. Details of bridge and machinery space control stations are to be submitted, e.g. control panels and consoles.

1.2.6 **Machinery configurations**. Plans showing the general arrangement of the machinery space, together with the layout and configuration of the main propulsion and other machinery for Mobility and/or Ship Type systems, are to be submitted.

■ *Section 2* Machinery arrangements

2.1 Main propulsion machinery

2.1.1 The main propulsion machinery may be oil engines, turbines or electric motors but the configuration of the propulsion system and its relationship with other systems is to comply with the remaining requirements of this Section.

2.1.2 The main propulsion machinery is to drive one of the generators required by *Vol 3, Pt 1, Ch 2, 2.2 Supply of electric power to Mobility and/or Ship Type systems 2.2.2*. This generator is to be capable of supplying the electrical load for Mobility and/or Ship Type systems under all normal sea-going and manoeuvring conditions.

2.1.3 Standby machinery is to be provided capable of being readily connected to the main propulsion system so as to provide emergency propulsion. This standby machinery is to be capable of connection so as to provide an alternative drive to the generator required in *Vol 3, Pt 1, Ch 2, 2.1 Main propulsion machinery 2.1.2*. It need not provide power to both systems simultaneously, *see also Vol 3, Pt 1, Ch 2, 2.2 Supply of electric power to Mobility and/or Ship Type systems 2.2.2*.

2.2 Supply of electric power to Mobility and/or Ship Type systems

2.2.1 Continuity of electrical power supply for Mobility and/or Ship Type systems is to be ensured under all normal sea-going and manoeuvring conditions without manual intervention in the machinery space. Methods by which this may be achieved include automatic start-up of generating sets and pumps for Mobility and/or Ship Type systems or manual start-up of these systems from the bridge.

2.2.2 Generating sets and converting sets are to be sufficient to ensure the operation of services essential for the propulsion and safety of the ship even when one generating set or converting set is out of service.

2.3 Controllable pitch propellers

2.3.1 For propulsion systems with controllable pitch propellers a standby or alternative power source for the actuating medium for controlling the pitch of the propeller blades is to be provided.

■ *Section 3* Control arrangements

3.1 Bridge control

3.1.1 Means are to be provided to ensure satisfactory control of propulsion from the bridge in both the ahead and astern directions when operating on either the main or standby engine(s).

3.1.2 Instrumentation to indicate the following is to be fitted on the bridge and at any other station from which the propulsion machinery may be controlled:

(a) Propeller speed.
(b) Direction of rotation of the propeller for a fixed pitch propeller.
(c) Pitch position for a controllable pitch propeller.
(d) Direction and an indication representative of the magnitude of thrust.
(e) Clutch position, where applicable.

3.1.3 An alarm is to operate in the event of a failure of the power supply to the bridge control system.

3.1.4 Emergency Stop Functions, independent of the bridge control system, are to be provided on the bridge to enable the watchkeeping officer to stop the main propulsion machinery in an emergency.

3.2 Alarm system

3.2.1 An alarm system is to be provided to indicate faults in Mobility and/or Ship Type machinery and control systems in accordance with this Chapter.

3.2.2 Machinery faults are to be indicated at the control stations on the bridge and in the machinery space.

3.2.3 In the event of a machinery fault occurring, the alarm system is to be such that the watchkeeping officer on the bridge is made aware of the following:

(a) A machinery fault has occurred.
(b) The machinery fault is being attended to.
(c) The machinery fault has been rectified. (Alternative means of communication between the bridge control station and the machinery control station may be used for this function.)

3.2.4 The alarm system should be designed with self-monitoring properties. As far as practicable, any fault in the alarm system should cause it to fail to the alarm condition.

3.2.5 The alarm system should be capable of being tested during normal machinery operation.

3.2.6 Failure of the power supply to the alarm system is to be indicated as a separate fault alarm.

3.2.7 Alarm indication is to be both audible and visual. If arrangements are made to silence audible signals they are not to extinguish visual alarms.

3.2.8 The acceptance of an alarm on the bridge is not to silence the audible signal in the machinery space.

3.2.9 Machinery signals should be distinguishable from other audible signals, e.g. fire, carbon dioxide.

3.2.10 Acknowledgement of visual alarms is to be clearly shown.

3.2.11 If the audible signal has been silenced and a second fault occurs before the first has been rectified, the audible signal is again to operate. To assist in the detection of transient faults which are subsequently self-correcting, fleeting alarms should lock in until accepted.

3.2.12 Arrangements should be made to enable alarm lights on the bridge to be dimmed as required, *see also Vol 2, Pt 10, Ch 1 Ergonomics*.

3.3 Communication

3.3.1 At least two means of communication are to be provided between the bridge and the control station in the machinery space. One of these means may be the bridge control system; the other is to be independent of the main electrical power supply.

3.3.2 The bridge, machinery space control station and any other control position from which the propulsion machinery can be controlled are to be fitted with means to indicate which station is in command.

3.3.3 Changeover between control stations is to be arranged so that it may only be effected with the acceptance of the stations taking control. The system is to be provided with interlocks or other suitable means to ensure effective transfer of control.

3.4 Engine starting safeguards

3.4.1 Where it is possible to start a main propulsion or auxiliary oil engine from the bridge, an indication that sufficient starting air pressure is available is to be provided on the bridge.

3.4.2 The number of automatic consecutive attempts which fail to produce a start is to be limited to safeguard sufficient starting air pressure, or, in the case of electric starting, a sufficient charge level in the batteries.

3.4.3 An alarm is to be provided for low starting air pressure, set at a limit which will still permit engine starting operations.

3.4.4 Where propulsion or auxiliary engines are started from the bridge, interlocks are to be provided to prevent starting of the engine under conditions which could hazard the machinery. These are to include ‘turning gear engaged’, ‘low lubricating oil pressure’, ‘shaft brake engaged’ and where machinery is not available due to maintenance or repairs.

3.5 Operational safeguards

3.5.1 Means are to be provided to prevent the machinery and shafting being subjected to excessive torque or other detrimental mechanical and thermal overloads.

3.5.2 Prolonged running in a restricted speed range is to be prevented automatically or, alternatively, an indication of restricted speed ranges is to be provided at each control station.

3.5.3 For ships propelled by steam turbines, the risk of thermal distortion of the turbines is to be prevented by automatic steam spinning when the shaft is stopped in the manoeuvring mode. An audible and visual alarm is to operate on the bridge and in the machinery space when the shaft has been stopped for two minutes.

3.5.4 In the case of lubricating oil systems for main propulsion and standby engine(s), the engine(s) is to be stopped automatically on failure of the lubricating oil supply. The circuit and sensor employed for this automatic shutdown are to be additional to the alarm circuit and sensor required by *Vol 2, Pt 7, Ch 3, 8.5 Alarms*. Where means are provided to override the automatic shutdown required by this paragraph, the arrangements are to be such as to preclude inadvertent operation. Visual indication of operation of the override is to be fitted.

3.5.5 In the case of oil engines, oil mist monitoring is to be provided for crankcase protection where arrangements are fitted to override the automatic stop for failure of the lubricating oil supply.

3.5.6 Boilers with automatic controls which under normal operating conditions do not require any manual intervention by the operators are to be provided with safety arrangements which automatically shut-off the fuel oil to all the burners in the event of either low water level or combustion air failure. Fuel oil is to be shut off automatically to any burner in the event of flame failure.

3.5.7 Arrangements are to be provided to stop propulsion gas turbines automatically for the following fault conditions:

(a) Overspeed, *see Vol 2, Pt 2, Ch 2, 8 Gas turbine package sub-systems*.
(b) High exhaust temperature, *see Vol 2, Pt 2, Ch 2, 8 Gas turbine package sub-systems*.
(c) Flame failure, or
(d) Excessive vibration.

3.5.8 Where standby pumps are arranged to start automatically in the event of low discharge pressure from the working pump, an alarm is to be given to indicate when the standby pump has started.

3.6 Automatic control of Mobility and/or Ship Type systems

3.6.1 All control systems for Mobility and/or Ship Type systems are to be stable throughout the operating range of the main propulsion machinery.

3.6.2 The temperature of the following is to be automatically controlled within normal operating limits:

Oil engines:

(a) Lubricating oil to the main engine and/or auxiliary engines.
(b) Fuel oil – temperature or viscosity.
(c) Piston coolant, where applicable.
(d) Cylinder coolant main and auxiliary engines, where applicable.
(e) Fuel valve coolant, where applicable.

Steam plant:

(a) Lubricating oil to main engine and/or auxiliary engines.
(b) Fuel oil to burners – temperature or viscosity.
(c) Superheated steam.
(d) External de-superheated steam.

Gas turbines:

(a) Lubricating oil to main engine and auxiliary engines.
(b) Fuel oil – temperature or viscosity.
(c) Exhaust gas.

3.6.3 The pressure of the following is to be automatically controlled within normal operating limits:

Steam plant:

(a) Superheated steam.
(b) Fuel oil.
(c) External de-superheated steam system(s).
(d) Gland steam.
(e) Reduced steam ranges.

3.6.4 The level of the following is to be automatically controlled within normal operating limits:

Steam plant:

(a) Boiler drum level.
(b) De-aerator level.
(c) Condenser level.

3.6.5 Boilers required for the operation of the propulsion of the vessel are to be provided with an automatic combustion control system.

3.7 Local control

3.7.1 The arrangements are to be such that Mobility and/or Ship Type machinery can be operated with the system of bridge control or any automatic controls out of action. Alternatively, the control systems should have sufficient redundancy so that failure of the control equipment in use does not render Mobility and/or Ship Type machinery inoperative.

■ *Section 1*
General requirements

1.1 General

1.1.1 This Chapter states the requirements for ships having machinery redundancy, and are in addition to the relevant requirements of the *Rules and Regulations for the Classification of Naval Ships* contained in *Vol 1 Ship Structures* and *Vol 2 Machinery and Engineering Systems*.

1.1.2 The requirements, which are optional, cover machinery arrangements and control systems necessary for ships which have propulsion and steering systems configured such that, in the event of a single failure of a system or item of active equipment, *see Vol 3, Pt 1, Ch 3, 1.1 General 1.1.4*, the ship will retain the ability to use available installed prime mover capacity and installed propulsion systems that are unaffected by the failure. The ship is also to retain steering capability at a service speed of not less than seven knots.

1.1.3 The requirements also cover machinery arrangements where the propulsion and steering systems are installed in separate compartments such that, in the event of a loss of one compartment, the ship will retain availability of propulsion power and manoeuvring capability.

1.1.4 For the purpose of this Chapter, items of active equipment are those which have a defined function for operation of a propulsion or steering system, such as:

- Prime movers;
- Generators and their excitation equipment;
- Transformers and converters;
- Dynamic braking resistors;
- Harmonic filters;
- Gearing;
- Pumps;
- Valves (where power actuated);
- Fuel treatment plant;
- Coolers/heaters;
- Filters;

Piping and electrical cables connecting items of active equipment are not considered to be active.

1.1.5 *Vol 3, Pt 1, Ch 3, 2 Risk Assessment (RA)*, *Vol 3, Pt 1, Ch 3, 3 Machinery arrangements* and *Vol 3, Pt 1, Ch 3, 4 Control arrangements* state the applicable requirements for arrangements necessary to maintain availability of propulsion and manoeuvring capability, in the event of a single failure in equipment. Ships complying with the applicable requirements of *Vol 3, Pt 1, Ch 3, 2 Risk Assessment (RA)* of this Chapter will be eligible for the machinery class notation **PMR** or **PMRL** (Propulsion Machinery Redundancy), **SMR** or **SMRL** (Steering Machinery Redundancy) or **PSMR** or **PSMRL** (Propulsion and Steering Machinery Redundancy).

Note The additional **L** character to **PMR**, **SMR** and **PSMR** notations indicates a limited capability.

1.1.6 *Vol 3, Pt 1, Ch 3, 5 Separate machinery spaces * (star) Enhancement* states the additional requirements necessary to maintain availability of propulsion and manoeuvring capability where machinery is installed in separate compartments and the loss of any one compartment due to fire or flooding has been addressed. Ships complying with the applicable requirements of *Vol 3, Pt 1, Ch 3, 2 Risk Assessment (RA)* of this Chapter will be eligible for the machinery class notation **PMR★** or **PMRL★** (Propulsion Machinery Redundancy in separate machinery spaces), **SMR★** or **SMRL★** (Steering Machinery Redundancy in separate machinery spaces) or **PSMR★** or **PSMRL★** (Propulsion and Steering Machinery Redundancy in separate machinery spaces).

1.1.7 For assignment of **PSMR** or **PSMR★** machinery class notations, the ship is to retain the ability to use not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems and retain steering capability at a service speed of not less than seven knots in the event of a single failure of a system or item of equipment.

1.1.8 Where the ship does not comply with *Vol 3, Pt 1, Ch 3, 1.1 General 1.1.7* but can retain a service speed of not less than seven knots using available installed prime mover capacity and propulsion systems (which may be less than 50 per cent) following a failure of a system or item of equipment, machinery class notations **PSMRL** or **PSMRL★** may be assigned. The available installed prime mover capacity and installed propulsion systems are to be identified and included in *Vol 3, Pt 1, Ch 3, 1.2 Documentation required for design review 1.2.7*.

1.2 Documentation required for design review

1.2.1 In addition to the plans and information required by this Part and *Vol 2, Pt 6 Steering Systems*, the information detailed in *Vol 3, Pt 1, Ch 3, 1.2 Documentation required for design review 1.2.2* is also to be submitted.

1.2.2 **Machinery spaces**. Plans showing the general arrangement of the machinery spaces are to be submitted. The plans are to indicate segregation and access arrangements for machinery spaces and associated control rooms/stations.

1.2.3 **Risk Assessment (RA)**. For the propulsion systems, electrical power supplies, control systems, steering arrangements, and other Mobility and/or Ship Type systems; a RA report is to be submitted and is to address the requirements identified in *Vol 3, Pt 1, Ch 3, 2 Risk Assessment (RA)* and *Vol 3, Pt 1, Ch 3, 5 Separate machinery spaces * (star) Enhancement*.

1.2.4 **Manoeuvring capability**. An assessment of the ship's ahead and astern manoeuvring capability, under the following operating conditions, is to be submitted:

(a) Where 50 per cent or less than the installed prime mover capacity and 50 per cent or less than the installed propulsion systems is available.
(b) Where the steering capability requirements described in *Vol 3, Pt 1, Ch 3, 3.2 Steering machinery 3.2.1* are available.

See IMO Resolution A.751(18) *Interim Standards for Ship Manoeuvrability* provides guidance on standard manoeuvres required in an assessment of the manoeuvrability of ships.

1.2.5 **Testing and trials procedures**. A schedule of testing and trials to demonstrate that the ship is capable of being operated with machinery functioning as described in *Vol 3, Pt 1, Ch 3, 3 Machinery arrangements* is to be submitted. In addition, any testing programme that may be necessary to prove the conclusions of the RA is to be submitted.

1.2.6 **Operating Manuals**. Operating Manuals are to be submitted for information and provided on board. The manuals are to include the following information:

(a) Particulars of machinery and control systems.
(b) General description of systems for propulsion and steering.
(c) Operating instructions for all machinery and control systems used for propulsion and steering.
(d) Procedures for dealing with the situations identified in the RA report.

1.2.7 **Installed prime mover capacity and installed propulsion systems.** System Operational Concept and System Design Description documents covering the propulsion system, main and emergency electrical power supply systems and steering arrangements are to be submitted. The System Operational Concept for the Propulsion systems is to include a schedule of the propulsion equipment and systems and their operating capacity and capability under normal and foreseeable failure conditions.

Section 2
Risk Assessment (RA)

2.1 General

2.1.1 A Risk Assessment (RA) is to be carried out in accordance with *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA) Vol 3, Pt 1, Ch 3, 2.1 General 2.1.2*, for the propulsion systems, electrical power supply systems and steering systems to demonstrate that a single failure in active equipment or loss of an associated sub-system, *see Vol 3, Pt 1, Ch 3, 1.1 General 1.1.4*, will not cause loss of all propulsion and/or steering capability as required by a class notation. Typical sub-systems include associated control and monitoring arrangements, data communications, power supplies (electrical, hydraulic or pneumatic), fuel, lubricating, cooling, etc.

2.1.2 The RA is to establish that in the event of a single failure:

(a) For **PSMR** and **PSMR*** notations, that not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems is available, and that steering capability is retained at a speed of seven knots.
(b) For **PMR** and **PMR*** notations, that not less than 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems remain available.
(c) For **SMR** and **SMR*** notations, steering capability at a speed of seven knots is to be retained.

2.1.3 For **PSMRL*** notation, that the ship will retain the ability to use available installed prime mover capacity and installed propulsion systems that are unaffected by the failure and retain steering capability at a service speed of not less than seven knots.

2.1.4 For **PMRL*** notation, that the ship will retain the ability to use available installed prime mover capacity and installed propulsion systems that are unaffected by the failure.

Section 3
Machinery arrangements

3.1 Main propulsion machinery

3.1.1 For **PSMR**, **PSMR★**, **PMR** and **PMR★** notations, independent main propulsion systems are to be provided so that at least 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems will continue to be available in the event of a single failure of a system or item of active equipment, *see Vol 3, Pt 1, Ch 3, 1.1 General 1.1.4*. In the event of a single failure in equipment, the remaining system(s) is to be capable of maintaining a manoeuvring speed and, for **PSMR** and **PSMR★** notations, give adequate manoeuvring capability, *see Vol 3, Pt 1, Ch 3, 1.2 Documentation required for design review 1.2.4*.

3.1.2 For **PMRL**, **PSMRL**, **PMRL★** and **PSMRL★** notations, independent main propulsion systems are to be provided so that the ship will retain the ability to use the available installed prime mover capacity and installed propulsion systems following a single failure of a system or item of equipment. In the event of a single failure in equipment, the remaining system(s) is to be capable of maintaining a manoeuvring speed of not less than 7 knots and, for **PSMRL** and **PSMRL★** notations, give adequate manoeuvring capability, *see Vol 3, Pt 1, Ch 3, 1.2 Documentation required for design review 1.2.4*.

3.2 Steering machinery

3.2.1 For **PSMR**, **PSMR★**, **SMR** and **SMR★** notations, independent steering systems for manoeuvring the ship are to be installed, such that steering capability will continue to be available in the event of any of the following:

(a) Single failure in the steering gear equipment.
(b) Loss of power supply or control system to any steering system.

3.3 Electrical power supply

3.3.1 The main busbars of the switchboard supplying the propulsion machinery and other Mobility and/or Ship Type systems are to be capable of being isolated by a multi-pole linked circuit breaker, disconnector, or switch-disconnector into at least two independent sections.

3.3.2 In the event of the loss of one section or failure of the power supply from one generator, there is to be continuity of sufficient electrical power to supply Mobility and/or Ship Type systems such that the available installed prime mover capacity and installed propulsion systems will continue to have the ability of functioning at their operational capability where **PSMRL**, **PSMRL★**, **PMRL** and **PMRL★** notations are required. *See Vol 3, Pt 1, Ch 3, 3.2 Steering machinery 3.2.1* for steering machinery requirements.

3.3.3 In the event of the loss of one section or failure of the power supply from one generator, there is to be continuity of sufficient electrical power to supply Mobility and/or Ship Type systems such that at least 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems will continue to be available where **PSMR**, **PSMR★**, **PMR** and **PMR★** notations are required. *See Vol 3, Pt 1, Ch 3, 3.2 Steering machinery 3.2.1* for steering machinery requirements.

3.3.4 For ships capable of operating with one service generator connected to the switchboard, arrangements are to be such that a standby generator will automatically start and connect to the switchboard on loss of the service generator. Sequential starting of Mobility and/or Ship Type systems is to be provided.

3.3.5 For ships operating with two or more generator sets in service connected to the switchboard, arrangements are to be such that, in the event of loss of one generator, the remaining set(s) is to be adequate for the continuity of Mobility and/or Ship Type systems supplied from that switchboard. This may be achieved by preferential tripping of services not required for the Mobility and/or Ship Type. Alternatively, arrangements can be such that a standby generator will start automatically and connect to the switchboard on loss of one of the generator sets in service.

3.4 Essential services for machinery

3.4.1 Services essential for the operation of the propulsion machinery, steering and the supply of electrical power are to be arranged so that 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems and steering capability are maintained in the event of a single failure in any of the services, where required by the respective class notations.

3.5 Fuel oil storage and transfer systems

3.5.1 The arrangements for the storage of fuel oil bunkers are to ensure that there is an adequate supply of existing fuel oil on board to allow sufficient time for a shore-based quality analysis of new bunkers, in accordance with ISO 8217 *Petroleum Products – Fuels (Class F) Specification of Marine Fuels* prior to use.

3.5.2 Provision is to be made to enable samples of fuel oil to be taken at the bunkering manifolds.

■ *Section 4*
Control arrangements

4.1 General

4.1.1 This Section states the requirements for the installation of control, alarm and safety systems but does not signify that machinery spaces may be operated unattended. For unattended machinery space operation, compliance with *Vol 2, Pt 9, Ch 1, 3 Quality of power supplies – ELS notation* is also required.

4.1.2 The control, alarm and safety systems required in *Vol 3, Pt 1, Ch 3, 4.2 Bridge control* are to comply with *Vol 2, Pt 9, Ch 8, 5 Programmable electronic systems (PES)*.

4.2 Bridge control

4.2.1 The controls, alarms, instrumentation and safeguards required in *Vol 3, Pt 1, Ch 3, 4.2 Bridge control 4.2.2*are to be provided on the bridge.

4.2.2 For **PSMR**, **PSMR★**, **PMR** and **PMR★** notations, means are to be provided to ensure satisfactory control of propulsion in both the ahead and astern directions when all main propulsion systems are functioning and when one propulsion system is not available.

4.2.3 For **PSMR**, **PSMR★**, **SMR** and **SMR★** notations, means are to be provided to ensure satisfactory control of steering when all steering systems are functioning and when any one steering system is not available.

4.2.4 Where required by *Vol 3, Pt 1, Ch 3, 5.4 Mobility and Ship Type systems for machinery 5.4.3*, isolation of Mobility and/or Ship Type systems is to be carried out either automatically or manually from the bridge. Indication of the status of isolation arrangements is to be provided on the machinery console.

4.2.5 A means of indicating the operational status of running and standby machinery is to be provided for the propulsion systems, the supply of electrical power, steering systems and other Mobility and/or Ship Type systems.

4.2.6 Alarms are to be provided in the event of:

(a) A fire in any machinery compartment.
(b) A high bilge level in any machinery compartment. Irrespective of the assignment of the **UMS** notation, the bilge level detection system and arrangements for automatically pumping bilges, if applicable, are to comply with *Vol 2, Pt 10, Ch 1, 6.5 Displays*.

■ *Section 5*
Separate machinery spaces * (star) Enhancement

5.1 General

5.1.1 This Section states the additional requirements where propulsion and steering machinery are installed separate compartments such that, in the event of the loss of one compartment, the ship will retain availability of propulsion power and manoeuvring capability.

5.1.2 The machinery arrangements, control arrangements and Risk Assessment (RA) required by *Vol 3, Pt 1, Ch 3, 2 Risk Assessment (RA)*, together with testing and trials requirements in *Vol 3, Pt 1, Ch 3, 6 Testing and trials*, are to be complied with in addition to *Vol 3, Pt 1, Ch 3, 5.2 Machinery arrangements*.

5.2 Machinery arrangements

5.2.1 The main propulsion machinery is to be arranged in not less than two compartments such that, in the event of the loss of one compartment, propulsion power and/or manoeuvring capability will continue to be available, where required by the respective class notations.

5.2.2 The steering systems are to be arranged in no fewer than two separate compartments, such that steering capability will continue to be available in the event of the loss of one compartment, where required by the respective class notations.

5.3 Electrical power supply

5.3.1 The generating sets and converting sets required by *Vol 3, Pt 1, Ch 3, 3.3 Electrical power supply 3.3.1* are to be arranged so that they are located in at least two separate machinery compartments.

5.3.2 The independent sections of the switchboard required by *Vol 3, Pt 1, Ch 3, 3.3 Electrical power supply 3.3.1* are to be arranged in no fewer than two separate compartments.

5.3.3 In the event of the loss of one compartment, there is to be continuity of sufficient electrical power to supply Mobility and/or Ship Type systems, such that propulsion power and steering capability will continue to be available.

5.4 Mobility and Ship Type systems for machinery

5.4.1 Services essential for the operation of the propulsion machinery, steering and the supply of electrical power are to be arranged, so that propulsion power and steering capability are maintained in the event of the loss of one machinery compartment.

5.4.2 The design of systems which may have a common source, such as those used for supplying fuel oil, lubricating oil, fresh and sea-water cooling, ventilation of compartments and engine starting energy, is to ensure continuous availability of supply in the event of the loss of any one compartment. Where applicable, continuous availability of heating services, fuel oil and water treatments is also to be provided. *See Vol 3, Pt 1, Ch 3, 3.5 Fuel oil storage and transfer systems* and *Vol 3, Pt 1, Ch 3, 5.6 Fuel oil storage* for fuel oil storage and transfer systems.

5.4.3 Where Mobility or Ship Type systems are arranged so that they may supply machinery in another compartment, means of isolation from that compartment is to be provided.

5.4.4 Where pumps for Mobility or Ship Type systems are arranged to supply more than one compartment, standby pumps for the same supplies are to be provided in a different compartment. The standby pumps are to be arranged to start automatically if the discharge pressure from the working pumps falls below a predetermined value.

5.5 Bilge drainage arrangements

5.5.1 The drainage arrangements for any machinery space are to be provided with means of isolation from other compartments.

5.6 Fuel oil storage

5.6.1 The fuel oil service tanks required by *Vol 2, Pt 7, Ch 3, 4.17 Fuel oil service tanks 4.17.2* are to be located in separate compartments.

5.6.2 Provision is to be made to ensure that fuel oil preparation and transfer arrangements to the fuel oil service tanks are continuously available in the event of the loss of any one compartment, *see also Vol 3, Pt 1, Ch 3, 5.4 Mobility and Ship Type systems for machinery 5.4.2*.

5.7 Fire containment

5.7.1 Common boundaries separating compartments containing propulsion and/or steering machinery are to be at least ‘A-30’ class divisions.

5.8 Risk Assessment (RA)

5.8.1 The RA required by *Vol 3, Pt 1, Ch 3, 2.1 General 2.1.1* for the propulsion systems, electrical power supplies, control systems, steering arrangements and other Mobility and/or Ship Type systems is also to address the following:

(a) Fire in a machinery space or control room.
(b) Flooding of any watertight compartment which could affect propulsion or steering capability.
(c) Separation of machinery spaces.

■ *Section 6*
Testing and trials

6.1 Sea trials

6.1.1 In addition to the requirements for sea trials in *Vol 2, Pt 1, Ch 3, 16.1 Sea trials requirements*, trials are to be carried out to demonstrate that when the ship is operating with 50 per cent of the installed prime mover capacity and not less than 50 per cent of the installed propulsion systems, a manoeuvring speed can be maintained with adequate steering capability, where required by the respective class notations.

6.1.2 Trials are to be carried out to demonstrate the ship's steering capability in accordance with the assessment required by *Vol 3, Pt 1, Ch 3, 1.2 Documentation required for design review 1.2.4* with one steering system out of action.

6.1.3 Where the Risk Assessment report has identified the need to prove the conclusions, testing and trials are to be carried out as necessary to investigate the following:

(a) The effect of a specific component failure.
(b) The effectiveness of automatic/manual isolation systems.
(c) The behaviour of any interlocks that may inhibit operation of Mobility or Ship Type systems.

6.1.4 During sea trials, the operational envelope(s) is to be determined under conditions detailed in *Vol 3, Pt 1, Ch 3, 3.1 Main propulsion machinery* or *Vol 3, Pt 1, Ch 3, 3.2 Steering machinery* as required for the class notation.

■ *Section 1* General

1.1 Application

1.1.1 The requirements contained in these Rules apply to naval ships of all rudder and propulsion types, where the length between perpendiculars, L_{pp}, is 50 m and over. Special consideration may be given to applying these requirements to smaller vessels.

1.1.2 These requirements, which are optional, establish a ship's manoeuvring capability by assessing its characteristics in conjunction with engine and propulsion performance. Such requirements are additional to those applicable in the *Rules and Regulations for the Classification of Naval Ships* (hereinafter referred to as the Rules for Naval Ships) contained in *Vol 1 Ship Structures* and *Vol 2 Machinery and Engineering Systems*.

1.1.3 Where a ship's manoeuvring capability is assessed and verified in accordance with these Rules, it will be eligible for the class notations specified in *Vol 3, Pt 1, Ch 4, 1.2 Class notations*.

1.1.4 For a ship under construction, the requirements of *Vol 3, Pt 1, Ch 4, 2 Assessment for LMA notation* or *Vol 3, Pt 1, Ch 4, 3 Assessment for LNMA notation* are to be met as applicable.

1.1.5 For an existing ship, all available data and full-scale manoeuvring information are to be submitted. This information will be examined against the requirements of these Rules and, if acceptable, the scope of the representative manoeuvres required in *Vol 3, Pt 1, Ch 4, 4 Verification trials* may be reduced.

1.1.6 Where the **LMA** notation is applied, these Rules satisfy the requirements of *IMO Resolution A.601(15) – Provision and Display of Manoeuvring Information on Board Ships – (Adopted on 19 November 1987)* and *Resolution MSC.137(76) - Standards for Ship Manoeuvrability - (adopted on 4 December 2002)* .

1.1.7 Where the **LNMA** notation is applied, these Rules enable LR to verify compliance with the minimum manoeuvring performance criteria defined in STANAG 4721 *Common Framework for Naval Surface Ship Manoeuvring Performance and Requirements*.

1.2 Class notations

1.2.1 In addition to the hull and machinery class notations defined in *Vol 1, Pt 1, Ch 2, 3 Character of Classification and Class notations*, ships complying with these requirements will be eligible to be assigned the notations:

LMA	Lloyd's Manoeuvring Assessment, *see Vol 3, Pt 1, Ch 4, 2 Assessment for LMA notation*.
LNMA	Lloyd's Naval Manoeuvring Assessment, *see Vol 3, Pt 1, Ch 4, 3 Assessment for LNMA notation*.

1.2.2 Details of any subsequent modifications to the ship's structure or equipment resulting in any alteration to the data specified in *Vol 3, Pt 1, Ch 4, 1.3 Information and Documentation required for design review* are to be submitted for re-assessment of the ship's manoeuvring capability.

1.3 Information and Documentation required for design review

1.3.1 Information required for **LNMA** assessment:

- Mission type justification report, *see Vol 3, Pt 1, Ch 4, 3.2 Manoeuvring performance criteria 3.2.1*;
- Ship specific manoeuvring performance criteria, *see Vol 3, Pt 1, Ch 4, 3.2 Manoeuvring performance criteria 3.2.3*;
- Simulation report;
- Model test report.

1.3.2 Information required for **LMA** assessment:

(a) Ship data, where applicable, *see Vol 1, Pt 3, Ch 1, 5 Definitions* of the Rules for Naval Ships:

- Length overall.
- Length between perpendiculars (L_{pp}).
- Moulded breadth.
- Draught at forward perpendicular.
- Draught at after perpendicular.
- Block coefficient and/or prismatic coefficient.
- Midship or maximum section area coefficient.
- Waterplane area coefficient.
- Distance of LCG from amidships (positive fwd).
- Height of VCG above baseline.
- Cross-sectional area of bulbous bow, if applicable, at the forward perpendicular below the load waterline.
- Wetted area of appendages, excluding rudder and propeller.
- Transverse metacentric height above baseline.
- Extreme height of the ship structure above baseline.

(b) Propeller data:

- Number of propellers and direction of rotation.
- Athwartship position of propellers.
- Height from baseline, to propeller axis.
- Longitudinal distance of propeller disc from amidships.
- Type of propellers (e.g. fixed or controllable pitch, ducted).
- If ducted, type of duct (e.g. accelerating/decelerating) and designation (e.g. NSMB 19A/37 or special type).
- Propeller diameter.
- Mean pitch for fixed pitch propellers.
- Design pitch and range of pitch for controllable pitch propellers.
- Number of blades.
- Developed blade area ratio.

(c) Rudder data:

- Number of rudders and type.
- If active type, rudder characteristics (e.g. rotating cylinder, variable fin, flap length, tail angle).
- Lateral underwater projected area of both rudder and horn, where applicable, *see* shaded area in *Figure 4.1.1 Mean height of rudder, H_R*.
- Mean height of rudder, H_R, *see Figure 4.1.1 Mean height of rudder, H_R*.
- Longitudinal distance of rudder's leading edge from amidships.
- Maximum rudder angle.
- Minimum time taken to put rudder over from 35 degrees on either side to 30° on the other side, *see Vol 2, Pt 6, Ch 1 Steering Gear*.

(d) Propulsion data:

- Propulsion type (e.g. gas turbine, electric, steam, diesel).
- Steady-state developed shaft torque or ship's speed versus propeller RPM/pitch at each telegraph or combinator setting as identified on the bridge. Times for effecting changes in engine telegraph settings for both normal and emergency conditions.
- Critical or barred RPM ranges.

- Main engine stalling revs, if applicable.

(e) Transverse thruster data, if applicable:

- Type of thruster (e.g. tunnel, Gill).
- Longitudinal distance of thruster axis from amidships.
- Thruster propeller characteristics, *viz*: number of blades, diameter and pitch.
- Power at MCR.
- Time delay to achieve full thruster RPM.
- Time delay to achieve full reverse RPM/pitch.
- Predicted thrust versus RPM/pitch curve in clear deep water.
- Thruster tunnel diameter and height of its centre above the keel.
- Details of hull profile in the vicinity of thruster tunnel.

(f) Side fins, *see Figure 4.1.2 Side fin dimensions*:

- Lateral fin area, *see* shaded area in *Figure 4.1.2 Side fin dimensions*.
- Height of fin, H_F.
- Longitudinal position of the fin, X_F, from amidships (positive fwd).
- Lateral position of the fin, Y_F, from the centreline.

(g) Wind parameters:

- Lateral projected area above waterline.
- Transverse projected area above waterline.
- Lateral projected area of the superstructure.
- Sum of the lengths forming the perimeter of the lateral projection of the ship, excluding waterline.
- Distance from the FP to the centroid of the lateral projected area.

(h) Ship performance data:

- Ship design speed.
- Propeller RPM at ship design speed.
- Power and percentage MCR to which ship speed and RPM apply.
- Draught conditions applicable to powering condition.
- Range of operating draughts and trims.
- Sea-state applicable to powering condition.
- RPM margin on propeller in the case of a new ship.

(i) Plans:

- A general arrangement plan of the ship.
- A lines plan.
- Forward and after bridge blind zones with dimensions specified.

(j) Manoeuvring information:

- Wheelhouse poster and manoeuvring booklet, *see Vol 3, Pt 1, Ch 4, 2.5 Wheelhouse poster and manoeuvring booklet*.

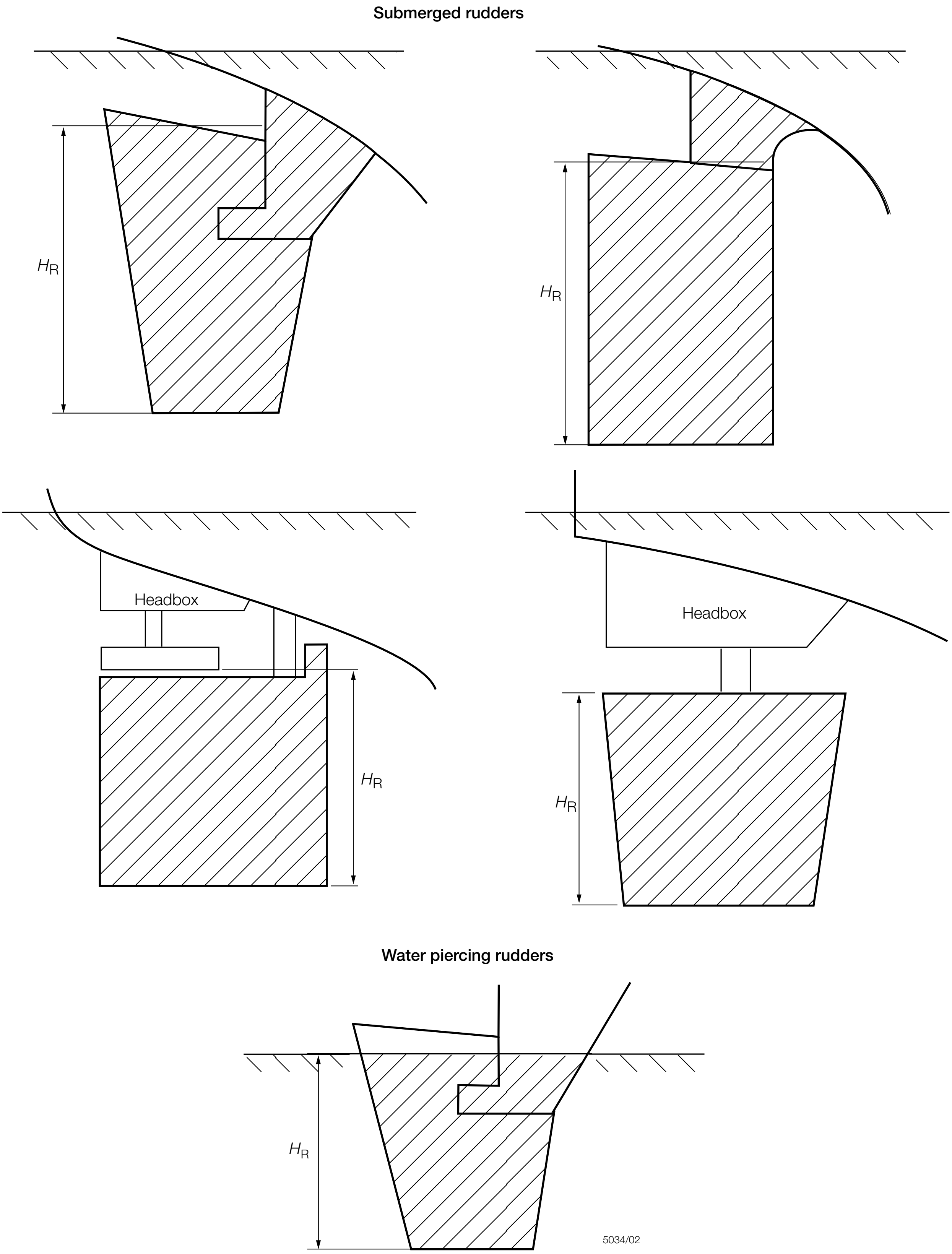


Figure 4.1.1 Mean height of rudder, H_R

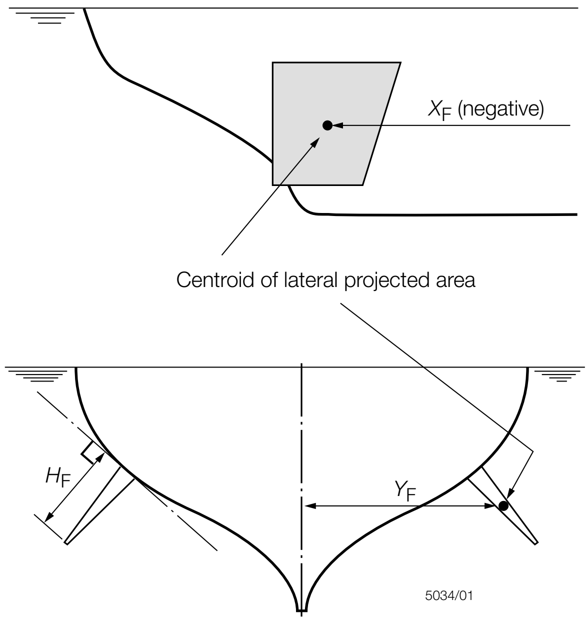


Figure 4.1.2 Side fin dimensions

1.4 Sister ships

1.4.1 In so far as these Rules are concerned, a ship will be deemed a sister ship, if that ship has been built to the same plans as the lead ship which has completed a manoeuvring assessment in accordance with the requirements of this Chapter.

1.4.2 In demonstrating that a ship is a sister ship, the hull dimensions, weights, tank capacities and arrangements, engine power and propulsion, rudder, performance and general superstructure design are to be identical.

1.4.3 The manoeuvring information for the lead ship may be used for the sister ship. All duplicate data is to be marked, 'Data duplicated from sister ship (name of lead ship)'.

1.4.4 For a sister ship to a ship carrying the **LMA** notation, the ship will be required to carry out the following representative manoeuvres, in accordance with *Vol 3, Pt 1, Ch 4, 4 Verification trials*:

(a) A ship's stopping manoeuvre from full sea speed achieved by the application of full astern thrust.
(b) A 10°/10° zig-zag manoeuvre under the approach conditions defined in *Vol 3, Pt 1, Ch 4, 4.4 Approach conditions*.
(c) A 20°/20° zig-zag manoeuvre under the approach conditions defined in *Vol 3, Pt 1, Ch 4, 4.4 Approach conditions*.
(d) An initial turning trial under the approach conditions defined in *Vol 3, Pt 1, Ch 4, 4.4 Approach conditions*.

1.4.5 For a sister ship to a ship carrying the **LNMA** notation the ship will be required to verify performance at sea trials. The manoeuvring performance criteria to be achieved are to be the same as those applied for the lead ship. The manoeuvres which are required to be repeated for a sister ship are shown in *Table 4.1.1 Required submissions according to design phase*.

Table 4.1.1 Required submissions according to design phase

Performance test	Detailed design	Acceptance trials
Zig-zag	S, M	T
Turning	S, M	T, T2
Accelerating turning	M	T
Turning at rest		T
Course keeping	S, M	T

Astern course keeping	M	T
Track keeping	S, M	T
Station keeping	S, M	T
Stopping test	S	T, T2
Acceleration/deceleration	S	T
SDNE		T, T2
Pull out, spiral test	S, M	T
Note S = Simulation, M = Model tests, T = Trials of first ship, T2 = Trials of sister ships		

■ *Section 2* Assessment for LMA notation

2.1 General

2.1.1 For the assignment of the **LMA** notation, calculations are to be carried out using the information specified in *Vol 3, Pt 1, Ch 4, 1.3 Information and Documentation required for design review* to produce an estimation of the ship's manoeuvring capability which must satisfy the requirements of *Vol 3, Pt 1, Ch 4, 2.3 Manoeuvring standards*.

2.1.2 The calculations are to be undertaken by the designer or Shipbuilder and submitted to Lloyd's Register (hereinafter referred to as 'LR') for review.

2.2 Manoeuvres to be assessed

2.2.1 The calculations are to give estimates of the primary manoeuvring indices from the following:

(a) Ship's turning circles to port and starboard with maximum design rudder angle starting from:

- The approach speed, *see Vol 3, Pt 1, Ch 4, 4.4 Approach conditions 4.4.1*, coupled with a pull-out manoeuvre.
- Full sea speed and constant engine(s) control setting.
- Half manoeuvring ship speed and constant engine(s) control setting.

(b) Ship's stopping manoeuvring characteristics by the application of astern power, from:

- The approach speed, *see Vol 3, Pt 1, Ch 4, 4.4 Approach conditions 4.4.1*.
- Full sea speed.
- Full manoeuvring speed ahead.
- Half manoeuvring speed ahead.
- Slow manoeuvring speed.

(c) Ship's yaw (rate of change of heading) checking characteristics through the 20º/20º and 10º/10º zig-zag manoeuvres, from the approach speed, *see Vol 3, Pt 1, Ch 4, 4.4 Approach conditions 4.4.1*, with constant engine(s) control setting.

(d) Ship's initial turning ability at the approach speed, *see Vol 3, Pt 1, Ch 4, 4.4 Approach conditions 4.4.1*.

(e) Where these manoeuvres indicate dynamic instability, additional representative manoeuvres may be required, for example, a spiral manoeuvre, *see Vol 3, Pt 1, Ch 4, 4.5 Representative manoeuvres (LMA notation) 4.5.2*.

2.2.2 For the purpose of the calculations, thrust breakdown due to cavitation during manoeuvring conditions and the effects of wind, tide, current and shallow water may be ignored.

2.3 Manoeuvring standards

2.3.1 For the assignment of the **LMA** notation, the ship is to be assessed in accordance with the requirements of IMO *Resolution MSC.137(76) - Standards for Ship Manoeuvrability - (adopted on 4 December 2002)*.

2.3.2 In cases where a large displacement ship does not satisfy the stopping standard referred to in *Vol 3, Pt 1, Ch 4, 2.3 Manoeuvring standards 2.3.1*, special consideration will be given to the ship's stopping capability.

2.4 Model tests

2.4.1 Model tests may be carried out in lieu of calculations, provided that they reflect the conditions and manoeuvres defined in *Vol 3, Pt 1, Ch 4, 2.2 Manoeuvres to be assessed*. A report is to be submitted which details the test arrangements, ship's characteristics as defined in *Vol 3, Pt 1, Ch 4, 1.3 Information and Documentation required for design review* , schedule of tests and results presented in both diagrammatic and tabular form.

2.5 Wheelhouse poster and manoeuvring booklet

2.5.1 The results of the calculations required by *Vol 3, Pt 1, Ch 4, 2.2 Manoeuvres to be assessed* (stating the assumptions made), together with additional information gained from the verification trials, and trial data for the man overboard manoeuvre, are to be presented in diagrammatic and tabular form and included in a wheelhouse poster and a manoeuvring booklet.

2.5.2 The poster is to be permanently displayed in the wheelhouse, and is to contain a clear warning that the data presented is applicable to calm weather with no wind, waves or current. The booklet is to be placed on board and is to contain comprehensive details of the ship's manoeuvring characteristics.

2.5.3 The format, data and content of the wheelhouse poster and the manoeuvring booklet are to meet the requirements of *IMO Resolution A.601(15) – Provision and Display of Manoeuvring Information on Board Ships – (Adopted on 19 November 1987)*.

2.6 Manoeuvring information card

2.6.1 The manoeuvring information card is to contain a summary of the ship's manoeuvring capabilities and principal particulars and is to be kept on the wheelhouse for the information of the pilot. The format and data to be presented on this card are to satisfy the requirements of *IMO Resolution A.601(15) – Provision and Display of Manoeuvring Information on Board Ships – (Adopted on 19 November 1987)*.

■ *Section 3*
Assessment for LNMA notation

3.1 General

3.1.1 For assignment of the **LNMA** notation a ships manoeuvring performance shall be verified at the design stage through simulation and model tests, and validated during sea trials.

3.1.2 Detailed computations or simulation are to be undertaken in accordance with STANAG 4721, Section 5.2.1.2 and results are to be submitted to LR for review for the manoeuvring abilities defined in *Table 4.1.1 Required submissions according to design phase*.

3.1.3 The model tests are to be carried out by a recognised facility that is acceptable to LR and a report is to be submitted detailing the test arrangements, schedule of tests and results presented in both diagrammatic and tabular form. The model testing is to be undertaken in accordance with STANAG 4721, Section 5.2.2 and results are to be provided for the manoeuvring abilities defined in *Table 4.1.1 Required submissions according to design phase*.

3.1.4 Final verification of the assignment of the **LNMA** notation will be dependent on the results of sea trials, *see Vol 3, Pt 1, Ch 4, 4 Verification trials*.

3.2 Manoeuvring performance criteria

3.2.1 STANAG 4721 provides manoeuvring performance criteria in relation to NATO defined missions. Descriptions of these missions are given in STANAG 4721, Section 3.1. The NATO mission types which will be used to determine the ship's manoeuvring performance criteria are to be agreed between the Owner and the designer. For this purpose the designer is to develop a justification report which outlines how the missions selected are consistent with the CONOPS. The report format is to follow the Goal, Safety functional objectives and Mission Effectiveness functional objectives defined in STANAG 4721, Section 4.1 and 4.2 respectively. The justification report is to be approved by the Owner.

3.2.2 The Safety manoeuvring performance criteria are to be determined from STANAG 4721, Tables 4.1 to 4.3 and are to be achieved by all ships for which the notation is requested to be assigned.

3.2.3 The Mission Effectiveness manoeuvring performance criteria are to be determined from STANAG 4721, Tables 4.6 to 4.20 for the NATO missions determined for a specific ship in accordance with *Vol 3, Pt 1, Ch 4, 3.2 Manoeuvring performance criteria 3.2.1*. The 'required level' performance criteria as opposed to the 'target' performance criteria are to be achieved by that ship. The manoeuvring performance criteria are to be calculated for each mission type and manoeuvring ability using the required verification speed. These manoeuvring performance criteria, once calculated, are to be documented in a ship specific report for ease of reference.

3.2.4 The measures by which these criteria are to be assessed are provided in STANAG 4721, Table 3.12.

3.3 Wheelhouse poster and manoeuvring booklet

3.3.1 Following sea trials, further trials on an opportunity basis will be required to provide the ship with NATO/Partner for Peace (PfP) Wheelhouse poster and Pilot Card as specified in ANEP–79 as well as recommended operator guidance such as the Manoeuvring Handbook, *see* e.g. ANEP-70 Vol. II.

■ *Section 4*
Verification trials

4.1 General

4.1.1 For the assignment of the **LMA** or **LNMA** notation, representative manoeuvres are to be carried out during sea trials, in accordance with the guidelines in *Vol 3, Pt 1, Ch 4, 5 Guidelines on conducting ship verification trials*, to verify that the manoeuvring performance criteria defined in *Vol 3, Pt 1, Ch 4, 2 Assessment for LMA notation* or *Vol 3, Pt 1, Ch 4, 3 Assessment for LNMA notation* as applicable are achieved in practice.

4.1.2 Verification trials are normally to be performed with a clean hull and propeller in the presence, and to the satisfaction, of the LR Surveyor.

4.1.3 A report is to be submitted to LR detailing the test schedule and presenting the results of each manoeuvring trial in accordance with the guidelines in *Vol 3, Pt 1, Ch 4, 5 Guidelines on conducting ship verification trials*.

4.2 Environmental restrictions

4.2.1 The verification trials are to take place in deep, unconfined waters, to minimise the interactive effects of the sea bed topography. The environmental conditions are to be as follows:

LMA notation:

- The water depth is not to be less than four times the mean operational draught of the ship.
- The wind speed should not exceed Beaufort 5.
- The wave sea state should not exceed 4.

LNMA notation:

- The water depth is not to be less than 5 times the mean operational draught of the ship or $0{,}0747V^2$, whichever is greater.
- The wind speed should not exceed 15 knots.
- The wave sea state should not exceed 3.
- In both cases heavy swell is to be avoided.

4.2.2 The environmental conditions (wind, significant wave height, current and swell) are to be accurately recorded throughout the duration of the trials. The results of the trials are to be corrected to indicate the ship's manoeuvring capability under zero wind, waves and current.

4.3 Draught conditions

4.3.1 The trials are normally to be carried out with the ship in a normal operational condition within a five per cent deviation of the design draught and trim.

4.3.2 Where it is impractical to conduct trials at design draught, they may be conducted at a draught as close to the design draught as possible with minimum trim and sufficient propeller immersion.

4.3.3 Where trials are conducted in a condition other than that required by *Vol 3, Pt 1, Ch 4, 4.3 Draught conditions 4.3.1*, the necessary manoeuvring characteristics are to be estimated for the trial and full load condition using an acceptable method, and the results are to be submitted to LR for assessment.

4.4 Approach conditions

4.4.1 The approach speed for the assessment under *Vol 3, Pt 1, Ch 4, 2 Assessment for LMA notation* (**LMA** notation) is to be at least 90 per cent of the ship's speed corresponding to 85 per cent of the maximum engine output.

4.4.2 The approach speed for the assessment under *Vol 3, Pt 1, Ch 4, 3 Assessment for LNMA notation* (**LNMA** notation) is to be the required verification speed for that mission type.

4.4.3 Before the execution of the relevant manoeuvre, the ship must have run at constant engine(s) setting with minimum rate of change of heading (steady course).

4.5 Representative manoeuvres (LMA notation)

4.5.1 Representative manoeuvres are to be carried out to an agreed trials code, and are to include the following:

(a) The performing of one turning circle to port and one to starboard with 35 degrees rudder angle (or the maximum rudder angle) for the following approach conditions:

- Conditions defined in *Vol 3, Pt 1, Ch 4, 4.4 Approach conditions*, coupled with a pull-out manoeuvre.
- Full sea speed.
- Half manoeuvring speed.

(b) Ship's stopping manoeuvre from full ahead manoeuvring speed achieved by stopping the engine.
(c) Ship's stopping manoeuvre from full sea speed achieved by the application of full astern thrust.
(d) Ship's stopping manoeuvre from the approach conditions, defined in *Vol 3, Pt 1, Ch 4, 4.4 Approach conditions*, achieved by the application of full astern power.
(e) A 10º/10º zig-zag manoeuvre, under the approach conditions defined in *Vol 3, Pt 1, Ch 4, 4.4 Approach conditions*.
(f) A 20º/20º zig-zag manoeuvre, under the approach conditions defined in *Vol 3, Pt 1, Ch 4, 4.4 Approach conditions*.
(g) Initial turning manoeuvre at the approach conditions defined in *Vol 3, Pt 1, Ch 4, 4.4 Approach conditions*.
(h) Man overboard manoeuvre, such as the Williamson turn or an elliptical turn, to both port and starboard at full sea speed.
(i) Transverse thruster manoeuvres, if applicable, with the ship stopped and all thrusters at maximum power to turn the ship 180 degrees to port and to starboard.

4.5.2 Provision is to be made in the trials agenda for the execution of a spiral manoeuvre where the results of the pullout manoeuvre indicate excessive dynamic instability or the values for either the first or second overshoot angles, measured during the 10º/10º zig-zag manoeuvre, exceed the following:

L/V (seconds)	First Overshoot Angle (degrees)	Second Overshoot Angle (degrees)
<10	10	25
$10 \leq L/V \leq 30$	$5 + (0,5\ (L/V))$	$20 + (0,5\ (L/V))$
>30	20	35

where

L = length between perpendiculars (metres)

V = approach speed, defined in *Vol 3, Pt 1, Ch 4, 4.4 Approach conditions 4.4.1* (m/s).

4.6 Representative manoeuvres (LNMA notation)

4.6.1 Specific manoeuvres are to be carried out to an agreed trials code. The scope of the manoeuvres is to be agreed between LR, the Owner and the Naval Administration in the sea trials procedures.

Section 5
Guidelines on conducting ship verification trials

5.1 General

5.1.1 These guidelines provide information on performing the verification trials in accordance with these Rules.

5.1.2 A detailed trials agenda is to be agreed before the commencement of any verification trials. This agenda should include:

- Agreement on the trials site.
- Notification of the possible restrictions that may be imposed by environmental conditions.
- A procedure to calibrate the data logging and measurement system.
- A procedure for data recording.
- The sequence in which the manoeuvring trials are to be conducted.
- The procedure for conducting each manoeuvre, including agreement on the starting and finishing points, the approach speeds and engine setting.

5.1.3 Environmental conditions can have a pronounced influence on the manoeuvring performance of a ship, therefore the verification trials are to be conducted within the environmental restrictions imposed by these Rules.

5.1.4 The following points are to be noted when determining the trials agenda:

- The ship's dynamic stability is required to be assessed in accordance with *Vol 3, Pt 1, Ch 4, 4.5 Representative manoeuvres (LMA notation) 4.5.2*. It is recommended that the pull-out manoeuvre is performed at the end of the turning circle manoeuvres, *see Vol 3, Pt 1, Ch 4, 5.5 Pull-out manoeuvring trials*.
- The initial turning ability of the ship, required by *Vol 3, Pt 1, Ch 4, 2.2 Manoeuvres to be assessed 2.2.1*, can be measured during the 10º/10º zig-zag manoeuvring trial, *see Vol 3, Pt 1, Ch 4, 5.7 Zig-zag manoeuvring trials*.

5.2 Calibration of the data logging and measurement system

5.2.1 Before commencing the verification trials, the data logging and measurement system is to be calibrated. The allowable measurement tolerances and the frequency of each measurement are given in *Table 4.5.1 Data measurement and accuracy requirements*.

5.2.2 The measurement system's time and the ship's time are to be synchronised with a recognised time signal. The time and date, relative to Universal Time Constant (UTC), are to be recorded.

Table 4.5.1 Data measurement and accuracy requirements

Parameter	Turning circles	Pull-out manoeuvres	Stopping/ Acceleration manoeuvres	Zig-zag manoeuvres	Spiral manoeuvres	Turning from rest manoeuvres	Man overboard manoeuvres	Minimum accuracy
Time	Continuously	Continuously	Continuously	Continuously	Continuously	Continuously	Continuously	± 1 sec
Position	Initially, and then at least every 45 degree change of heading		Initially, and then at least every 20 secs	At least 5 equally spaced measurements			Initially, then at least every 45 degree change of heading or 20 secs whichever is the lesser	± 10 metres
Forward speed	At least every 10 secs or 30 degree change of heading		At least every 5 secs	At least every 5 secs	Initially, then once at each steady rate of turn		At least every 5 secs	± 0,5 knots

Heading	At least every 5 secs	At least every 2 secs	At least every 20 secs	At least every 2 secs	At least every 2 secs	At least every 2 secs	At least every 2 secs	± 0,5 degrees
Rudder angle	Initially, and then at least every 45 degree change of heading	At least every 2 secs	Initially, and then periodically to check the rudder is amidships	At least every 2 secs	One for each steady rate of turn	Initially, and then periodically to check the rudder is hard over	At least every 5 secs	± 1 degree
Engine RPM	Initially, and then at least every 45 degree change of heading		Initially, and then at least every 5 secs	Initially, and then at least every crossing of the base course	Initially, and then once at each steady rate of turn		Initially, then when the rudder is reversed and at the end of the manoeuvre	± 1% of initial setting
Rate of turn	At least every 5 secs	At least every 2 secs		At least every 5 secs	At least every 5 secs	At least every 2 secs		± 0,05 degrees/sec
Note All parameters are to be measured at the initiation and termination points of each manoeuvring trial								

5.2.3 The position of the ship is to be determined by all available means and calibrated with range and/or bearing fixes from three prominent landmarks, including radar responding beacons (racons). Where the ship's position is to be measured using land-based transponders, the installation, set-up and calibration of such measurement equipment are to be carried out to the manufacturer's instructions.

5.2.4 The ship's speed over the ground is to be calibrated with range and/or bearing fixes from three prominent landmarks (including racons), whilst held on a steady course with no alteration in engine setting.

5.2.5 The gyro repeaters are to be adjusted until they are synchronized with the master gyro compass reading.

5.2.6 The steering gear is to be tested to calibrate the rudder angle indicator(s), over the full range of movement against the actual rudder angle reading given on the rudder stock.

5.2.7 The rate of turn indicator can be calibrated against the actual change in heading per second during a turn.

5.2.8 Where an automatic data logging and measurement system is to be used, the installation, set-up and calibration of such measurement equipment are to be carried out to the manufacturer's instructions.

5.2.9 The equipment used to measure prime mover/ propeller shaft revolutions and shaft power (torsion meters) is to be calibrated before trials.

5.3 Data recording

5.3.1 The data describing manoeuvring performance is to be measured and recorded in accordance with the requirements of *Table 4.5.1 Data measurement and accuracy requirements*. This data is to be measured and recorded from the start of the approach run and terminated at the end of the manoeuvring trial. The start of the manoeuvring trial is to be defined by a specific engine order or helm change noted on the recorded measurements.

5.3.2 An automatic data logging and measurement system is the preferred option. However, where the manoeuvring data is to be recorded manually, it is necessary to have suitable indicators and repeaters available to allow a sufficient number of persons to record the required parameters. Sufficient personnel are to be present to ensure that each person is recording no more than three parameters in each trial.

5.3.3 All recordings are to be synchronized to a common time datum.

5.3.4 The following data is to be clearly recorded for each trial manoeuvre:

(a) Date.
(b) Time.
(c) Ship's loading condition (draught and trim).

(d) Initial approach speed and heading.
(e) Water depth.
(f) Environmental conditions, including:

current speed and direction;

wind speed;

wind direction relative to the ship's head;

sea state.

(g) Position (latitude and longitude) (The use of calibrated GPS systems is acceptable.)
(h) Ship's heading.
(i) Rate of turn.
(j) Speed.
(k) Rudder angle.
(l) Propeller revolutions.
(m) Propeller pitch, where applicable.

5.3.5 The steady approach conditions for each trial are to be recorded for at least two minutes before the initiation of the manoeuvring trial.

5.4 Turning circle manoeuvring trials

5.4.1 These trials measure the effectiveness of the rudder(s) in initiating a turn and the ship's steady state turning characteristics.

5.4.2 The turning circle manoeuvre is to be conducted as follows:

(a) It is to be initiated when:
   (i) the relative approach condition defined in *Vol 3, Pt 1, Ch 4, 4.4 Approach conditions* is satisfied and the ship is running head to wind; and
   (ii) the rudder is ordered hard over to port or starboard.
(b) It must continue without any alteration to the engine control settings.
(c) It is to be terminated when the ship has completed a 540° turn.

5.4.3 The following information is to be derived from the trials data, *see Figure 4.5.1 Presentation of turning circle manoeuvring trial results*:

(a) Time taken to reach each 90° change of heading.
(b) Advance at each 90° change of heading.
(c) Transfer at each 90° change of heading.
(d) Tactical diameter.
(e) Steady turning diameter.
(f) Loss in forward speed during the turn.
(g) Rate of turn during the turn, r, *see Vol 3, Pt 1, Ch 4, 5.9 Spiral manoeuvring trials 5.9.5*

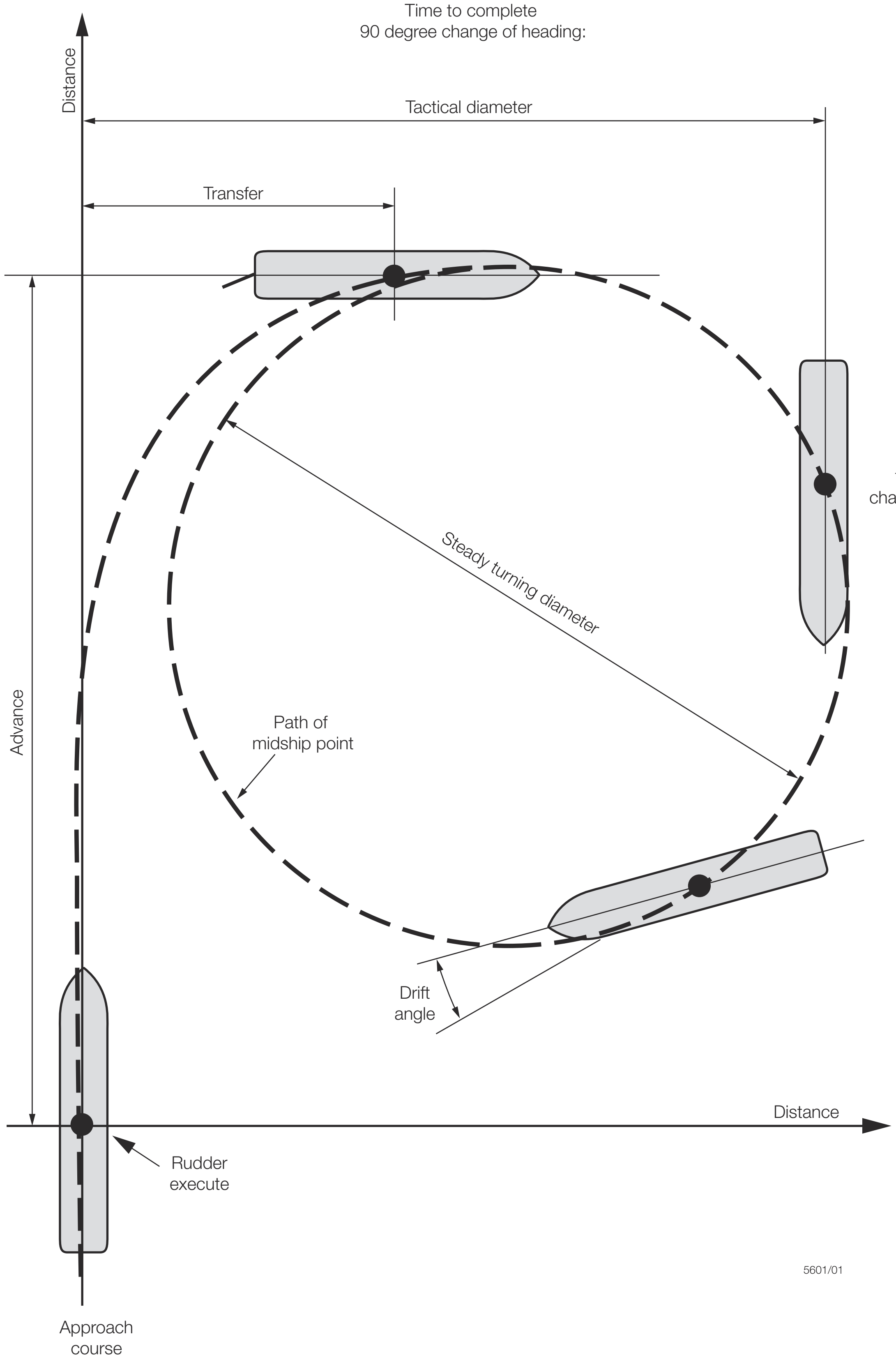


Figure 4.5.1 Presentation of turning circle manoeuvring trial results

5.5 Pull-out manoeuvring trials

5.5.1 The pull-out manoeuvre is a simple trial which has been developed to give a quick indication of the ship's dynamic stability and course keeping ability. The pull-out manoeuvre is to be performed at the end of each turning circle manoeuvring trial. The results of these manoeuvres will indicate whether a spiral manoeuvre trial is required to be conducted, *see Vol 3, Pt 1, Ch 4, 5.9 Spiral manoeuvring trials*.

5.5.2 The pull-out manoeuvre is to be conducted as follows:

(a) The ship is to be in a steady state turn (constant rate of turn) with the rudder hard over. This manoeuvre is normally conducted on the termination of the turning circle manoeuvring trial.
(b) This manoeuvre is initiated when the rudder is ordered amidships.
(c) With the rudder held amidships, the rate of turn will decrease.
(d) If the ship possesses 'dynamic stability', the rate of turn will reduce towards zero with equal residual rates of turn for both port and starboard turns with the rudder held amidships. If there is an unequal residual rate of turn with the rudder held amidships, then the ship is to be considered 'dynamically unstable', *see Figure 4.5.2 Presentation of pull-out manoeuvring trial results*.

5.5.3 The following information is to be derived from the trials data, and presented as shown in *Figure 4.5.2 Presentation of pull-out manoeuvring trial results*:

A plot of the time histories of the ship's head, rate of turn and ship's speed.

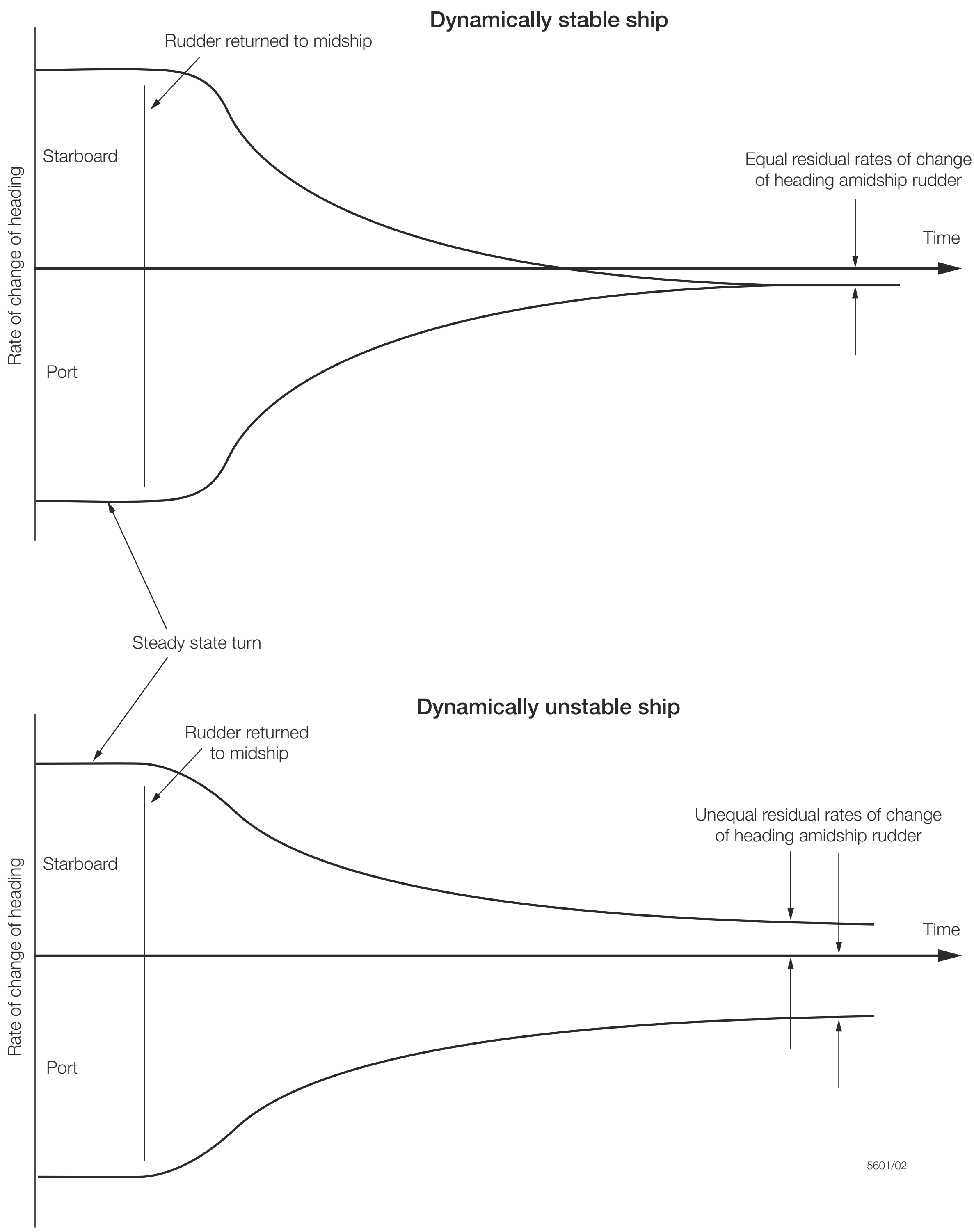


Figure 4.5.2 Presentation of pull-out manoeuvring trial results

5.6 Stopping trials

5.6.1 A ship's stopping performance is normally represented by the crash stop manoeuvre, which determines the stopping ability of the ship from the time an order of full astern is given until the ship stops dead in the water for a given approach speed. In

addition to the crash stop manoeuvre, a coasting stop manoeuvre is required to be conducted with the engines delivering no power to the propeller.

5.6.2 The stopping manoeuvre is to be conducted as follows:

(a) It is to be initiated when:

  (i) the relative approach conditions defined in *Vol 3, Pt 1, Ch 4, 4.4 Approach conditions* are satisfied and the ship is running with the wind astern, and
  (ii) the demand for full astern power or stop is given from the engine control position on the bridge.

(b) The rudder is to be used to a minimal extent and only to keep the ship on course for as long as possible.
(c) It is to be terminated when the ship has stopped dead in the water.

5.6.3 The following information is to be derived from the trials data, *see Figure 4.5.3 Presentation of both stopping trials' results*:

(a) Minimum speed at which course can be maintained.
(b) Head and track reach.
(c) Lateral deviation and final heading.
(d) Time to stop dead in the water.

5.7 Zig-zag manoeuvring trials

5.7.1 These trials measure the effectiveness of the rudder(s) to initiate and check changes in heading. This manoeuvre is normally defined as a θ_1/θ_2 zig-zag manoeuvre (e.g. 20°/20°) where:

(a) θ_1 is the required rudder angle, in degrees, to be applied during the trial, and
(b) θ_2 is the deviation, in degrees, of the ship's head, from the original course, before application of θ_1 to check changes in heading.

5.7.2 The zig-zag manoeuvre involves the cyclic movement of the ship about an initial base course. The zig-zag manoeuvre is conducted as follows:

(a) It is to be initiated when:

  (i) the approach conditions defined in *Vol 3, Pt 1, Ch 4, 4.4 Approach conditions* have been satisfied and the ship is running head to wind; and
  (ii) the rudder is ordered to θ_2 degrees to starboard (or port).

(b) It must continue without any alteration to the engine control settings.
(c) When the heading has changed by θ_2 degrees from the original course, the rudder is to be ordered to the opposite angle θ_1 degrees to port (or starboard).
(d) When the heading has changed by θ_1 degrees from the original course, the rudder is to be ordered to the opposite angle θ_2 degrees to starboard (or port).
(e) This manoeuvre is to be terminated when the ship's head has crossed the base course at least three times.

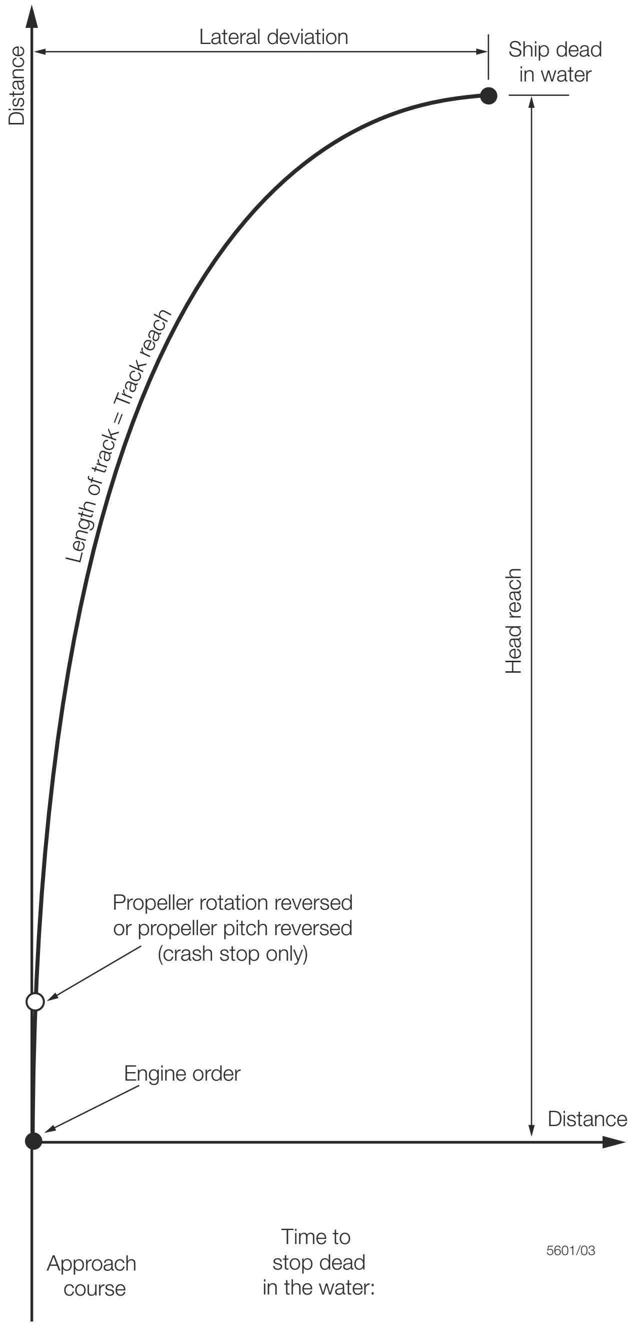


Figure 4.5.3 Presentation of both stopping trials' results

5.7.3 The following information is to be derived from the trials data, *see Figure 4.5.4 Presentation of zig-zag manoeuvring trial results*:

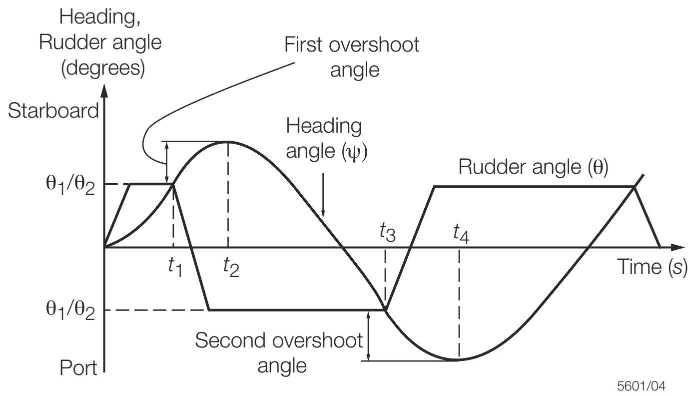
(a) A plot of the time histories of the rudder angles and corresponding ship's heading.

(b) First overshoot angle.

(c) Second overshoot angle.

(d) Time to check yaw (rate of change of heading equals zero) at each rudder reversal.

(e) Initial turning time.



t_1 = Initial turning time
$t_2 - t_1$ = Time to correct heading at first overshoot angle
$t_4 - t_3$ = Time to correct heading at second overshoot angle

Figure 4.5.4 Presentation of zig-zag manoeuvring trial results

5.8 Initial turning manoeuvring trials

5.8.1 The initial turning manoeuvring trial measures the transient effectiveness of the rudder(s). To ascertain the ship's initial turning ability, in accordance with *Vol 3, Pt 1, Ch 4, 4.4 Approach conditions*, the following data is to be recorded from the 10º/10º zig-zag manoeuvring trials:

When the ship's head has moved 10º off the base course, after the initial rudder command, the number of ship lengths travelled is to be recorded.

5.9 Spiral manoeuvring trials

5.9.1 This trial measures the ship's steady state rate of turn as a function of the applied rudder angle, providing a qualitative measure of the ship's dynamic stability.

5.9.2 There are two possible variations of the manoeuvring trials that can be used to assess the ship's dynamic stability, namely:

The direct, or Dieudonne, spiral manoeuvre.

The reverse, or Bech, spiral manoeuvre.

5.9.3 The direct spiral manoeuvre will yield more information about the degree of instability. However, this manoeuvre is very time-consuming, requires good weather conditions and, for larger ships, needs considerable sea room. The reverse spiral manoeuvre provides a procedure for defining the instability loop more rapidly than the direct spiral manoeuvre. However, this trial requires accurate rudder angle and rate of turn indicators. Where the ship is to be steered manually, the helmsman is to be able to read the rate of turn indicator.

5.9.4 The direct spiral manoeuvre is to be conducted as follows:

(a) It is to be initiated when:
  - (i) the approach conditions defined in *Vol 3, Pt 1, Ch 4, 4.4 Approach conditions* have been satisfied, and
  - (ii) the rudder is ordered to 25º to starboard.

(b) It must continue without any alteration to the engine control settings.

(c) The rudder is to be held until the indicated rate of turn is assumed constant.

(d) The rudder angle is then to be decreased by 5º and held until the rate of turn is assumed constant.

(e) The manoeuvre is to be terminated when the rudder has moved through the range of 25º to starboard to 25º to port and then back to 25º to starboard in incremental rudder angles of 5º.

(f) For dynamically unstable ships, the incremental rudder angle in the range of 10° to starboard through to 10° to port is to be 2°.

5.9.5 The reverse spiral manoeuvre is to be conducted as follows:

(a) It is to be initiated when:
   (i) the approach conditions defined in *Vol 3, Pt 1, Ch 4, 4.4 Approach conditions* have been satisfied; and
   (ii) the first constant rate of change of heading is achieved.

(b) It must continue without any alteration to the engine control settings.

(c) The recommended constant rates of turn are defined as percentages of the steady state rate of turn, *r*, derived from the turning circle, as shown in *Table 4.5.2 Recommended constant rate of change of heading*. For the **LNMA** notation specific constant rates of turn may be specified.

(d) The points P1 to P8 represent positions on the spiral curve, *see Figure 4.5.5 Presentation of spiral manoeuvring trial results for a dynamically unstable ship*.

(e) The first and last points on the spiral curves (P1 and P8) can be derived from the turning circle manoeuvres.

(f) The ship is to be steered at a constant rate of turn and the mean rudder angle to achieve the desired rate of turn is to be noted. The rudder angle deviations are not to be greater than ± 2°.

(g) The manoeuvre is to be terminated when all points have been determined.

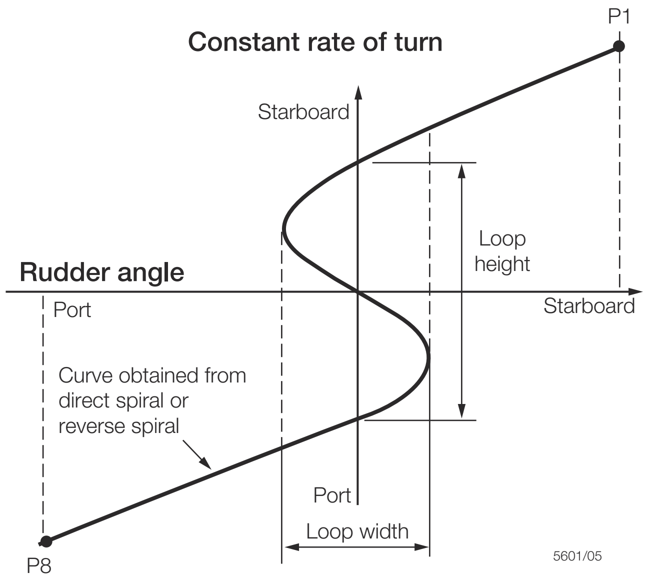
Table 4.5.2 Recommended constant rate of change of heading

Points	Rate of change of heading
P1 and P8	1,0 *r*
P2 and P7	0,6 *r*
P3 and P6	0,3 *r*
P4 and P5	0,1 *r*
where *r* = change of heading per second = $\frac{dY}{dt}$	

5.9.6 The following information is to be derived from the trials data, *see Figure 4.5.5 Presentation of spiral manoeuvring trial results for a dynamically unstable ship*:

(a) A time history of the rudder angle and corresponding rate of turn.

(b) A plot of the constant rate of turn as an ordinate against the applied rudder angle.



P1, P8 Rate of turn at maximum rudder angle
P2 to P7 Intermediate points which will form the curve which will represent the ship's dynamic stability, *see* Table 4.2

Figure 4.5.5 Presentation of spiral manoeuvring trial results for a dynamically unstable ship

5.10 Man overboard manoeuvring trials

5.10.1 The man overboard manoeuvre provides the Master with important information on the time taken and the deviation from course necessary to retrieve a person or object from the sea. The elliptical and Williamson turns are two well-known man overboard manoeuvres. These manoeuvres will, in the absence of wind and current, bring the ship back to the position where the man overboard incident occurred.

5.10.2 The elliptical turning manoeuvre is to be conducted as follows:

(a) It is to be initiated when:
   (i) the approach conditions defined in *Vol 3, Pt 1, Ch 4, 4.4 Approach conditions* have been satisfied, and
   (ii) the rudder is ordered hard over.
(b) It must continue without any alteration to the engine control settings.
(c) The rudder is to remain hard over until the ship has altered course by 180°. The ship is to be steadied on the reciprocal heading until the approach speed has been regained.
(d) The rudder is once again placed hard over and the ship is steadied on the original course.
(e) This manoeuvre is to be terminated when the ship has returned to the position, or nearest position, where the manoeuvre was initiated.

5.10.3 The Williamson turning manoeuvre is considered quicker than the elliptical turning manoeuvre in returning the ship to the original man overboard position. This manoeuvre is to be conducted as follows:

(a) It is to be initiated when:
   (i) the approach conditions defined in *Vol 3, Pt 1, Ch 4, 4.4 Approach conditions* have been satisfied, and
   (ii) the rudder is ordered hard over.
(b) It must continue without any alteration to the engine control settings.
(c) The rudder is to remain hard over until the ship has altered course by 70°. The rudder is then ordered hard over to the opposite side, until the ship is on a course which is the reciprocal of the original approach course.
(d) It is terminated when the ship has returned to the position, or nearest position, where the manoeuvre was initiated.

5.10.4 The following information is to be derived from the trials data, *see Figure 4.5.6 Presentation of the Williamson turn, man overboard, manoeuvring trial results*:

(a) A plot of the ship's track.
(b) The time taken to return to the point, or nearest position to that point, at which the manoeuvre was initiated.
(c) The lateral deviation from the initial course at the point, or nearest position to that point, at which the manoeuvre was initiated.

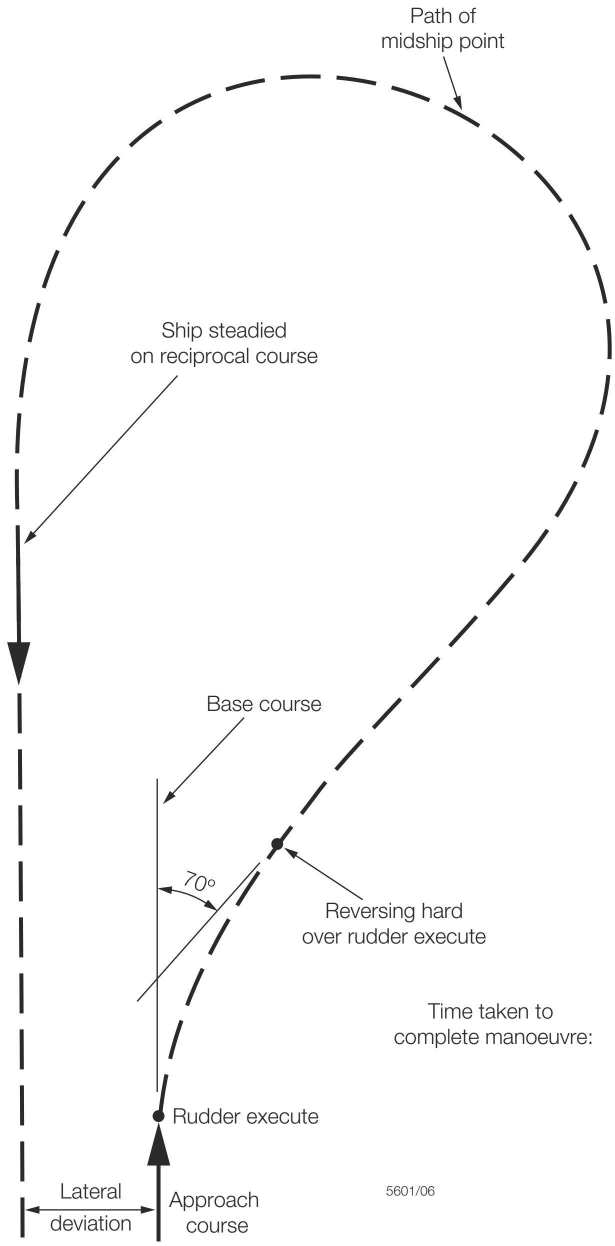


Figure 4.5.6 Presentation of the Williamson turn, man overboard, manoeuvring trial results

5.11 Manoeuvring trials for auxiliary thrusters

5.11.1 Where a ship is fitted with auxiliary thrusters, such as bow thrusters, a turning circle manoeuvre is required to be performed to determine the effectiveness of those thrusters in turning the ship through 180º. This trial is to be carried out with the wind initially from the stern and the ship turning into the wind.

5.11.2 The auxiliary thrusters' turning circle is to be conducted as follows:

(a) All primary thrusters stopped and the ship dead in the water.
(b) The ship is to be completely stopped in the water with head to wind.
(c) The auxiliary thrusters are to be set to maximum power to turn the ship.
(d) The manoeuvring trial is to be completed when the ship has turned through 180º.

5.11.3 The following information is to be derived from the trials data:

(a) The time taken to reach a 90º change of heading.
(b) The time taken to reach a 180º change of heading.
(c) The transfer at a 90º change of heading, *see Figure 4.5.1 Presentation of turning circle manoeuvring trial results*.
(d) The transfer at a 180º change of heading, *see Figure 4.5.1 Presentation of turning circle manoeuvring trial results*.
(e) The steady state rate of change of heading.

5.11.4 If required by *Vol 3, Pt 1, Ch 4, 3.2 Manoeuvring performance criteria* (**LNMA** notation only) a self berthing manoeuvre is to be carried out:

(a) The ship is to be positioned bow or stern to the wind.
(b) All primary thrusters stopped and the ship dead in the water.
(c) The auxiliary thrusters are to be set to maximum power for transverse motion.
(d) The manoeuvre may be terminated when the ship has recorded a steady transverse speed with zero rate of rotation.

5.11.5 The following information is to be derived from the trials data:

(a) The time taken to reach a steady transverse velocity.
(b) The maximum transverse velocity attained.
(c) The heading of the vessel at least every two seconds during the manoeuvre.

5.12 Acceleration trials

5.12.1 The acceleration trials information on the distance and time to achieve a speed defined by 80–100 per cent MCR set speeds from a dead stop.

5.12.2 The following trial procedure is to be followed as illustrated in *Figure 4.5.7 Acceleration trial*:

(a) Establish a steady ship speed in accordance with the trial agenda and adjust the ship's heading to a steady course. At a position roughly one ship length before the point where the engine order is initiated, start the acquisition system.
(b) Execute the prescribed engine order.
(c) The rudder is to be used to a minimal extent and only to keep the ship on course.
(d) When the ship attains the steady terminal speed stated in the trial agenda, the test is complete.

5.12.3 The following information is to be derived from the trials data:

(a) The time taken to reach the terminal speed specified in the trials agenda.
(b) The distance covered from the time the engine order is initiated until the ship reaches the terminal speed specified in the trials agenda.
(c) Lateral deviation and final heading.

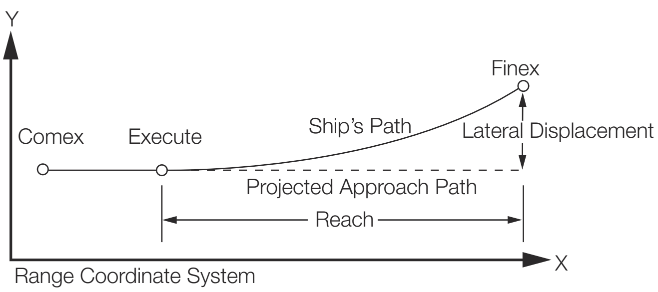


Figure 4.5.7 Acceleration trial

5.13 Turning from rest

5.13.1 The turning from rest manoeuvre is to be conducted as follows:

(a) All primary and auxiliary thrusters are stopped and the ship dead in the water;
(b) the rudder is ordered hard over;
(c) the demand for full ahead power is given from the engine control position on the bridge;
(d) the ship must continue without any alteration to the engine control settings;
(e) the rudder is to remain hard over until the ship has altered course by 90°;
(f) this manoeuvre is to be terminated when the ship has altered course by 90°.

5.13.2 The time taken from the full ahead order until the ship has altered course by 90° is to be recorded.

■ *Section 1*
General requirements

1.1 Application

1.1.1 This Chapter states the requirements for Replenishment At Sea (RAS) systems installed in naval ships for the purpose of supplying and receiving solid or liquid supplies. The Chapter also states the requirements for Vertical Replenishment (VERTREP) and light jackstay RAS systems which may be used for transfer of personnel and light stores between naval ships. The requirements are in addition to the relevant requirements contained in *Vol 1 Ship Structures* and *Vol 2 Machinery and Engineering Systems* of these Rules. Other arrangements to supply solid and liquid stores by means of RAS will be specially considered.

1.1.2 The requirements in this Chapter cover arrangements, deck equipment, piping and control systems necessary for RAS operations.

1.1.3 The extent of RAS systems and facilities are subject to agreement between the designer and Owner. The classification approval process will involve assessment of the safety of the proposed facilities from concept to through life operability and de-commissioning. RAS operations are extremely hazardous and those involved in the development of such systems need to address safety issues to minimise the risks to the ship, personnel and the environment. Operational procedures and regular crew training are essential to minimise these risks and to reduce hazards to as low as reasonably practicable.

1.1.4 NATO interoperability requirements are to be specified by the Owner/Operator and are detailed in ATP16 (latest version).

1.2 RAS terminology

1.2.1 RAS terminology is defined in *Vol 3, Pt 1, Ch 5, 1.2 RAS terminology 1.2.2*.

1.2.2 **RAS station**: The physical location of a combination of deck area and associated equipment that provides a ship with the capability to receive or deliver solids, liquid or personnel by means of passing RAS equipment between ships whilst underway. Note these Rules are only applicable to naval ships intended for supplying and receiving solid or liquid supplies and for personnel transfer.

1.2.3 **VERTREP Operational Area (VOA)**: This is the authorised area within which VERTREP operations are conducted. It includes the clear deck space for helicopter rotor, fuselage and landing gear, and VERTREP load clearances (including dump areas).

1.2.4 **Abeam Replenishment**: The transfer of solid cargo, personnel or liquid cargo by means of passing RAS equipment between ships while underway when the Receiving Ship will normally station-keep on the Supplying Ship. Circumstances may exist when the Supplying Ship will be required to station-keep on the Receiving Ship.

1.2.5 **Astern Replenishment**: The transfer of liquid cargo by means of a hose(s) while underway with the Receiving Ship maintaining station astern of the Supplying Ship.

1.2.6 **Vertical Replenishment (VERTREP)**: Transfer of solid cargo by underslung load from a helicopter and the winching of personnel where a ship is not provided with a flight deck.

1.2.7 **Supplying Ship**: The ship that supplies the RAS equipment and cargo.

1.2.8 **Receiving Ship**: The ship that receives the RAS equipment and transferred cargo.

1.2.9 **Dump Area**: A designated clear area that is provided at VERTREP and Abeam RAS stations for receiving stores.

1.3 Safety

1.3.1 Replenishment at sea between two vessels underway (particularly abeam RAS) is classified as the most hazardous peacetime seamanship evolution conducted by the naval and supply ships. It is important that the following areas are considered when designing, building, operating and maintaining RAS systems:

(a) **Close Proximity of Vessels Underway**: Station-keeping and the availability of propulsion and steering to maintain constant speed and heading are vital to avoid collision, due to the pressure interaction areas between ships in close proximity underway.
(b) **Handling of Explosives and Bulk Ammunition**: Replenishment of solids may include ammunition and explosives classified as UN hazard category 1. Particular note is to be taken of the enhanced factors of safety and equipment test periodicities that are required for mechanical handling equipment used for such purposes.
(c) **Transfer of Personnel and Explosives**: Lifting appliance codes of practice stipulate enhanced factors of safety and more frequent testing for preventive maintenance of mechanical handling equipment used for transfer of personnel and explosives.
(d) **Safety of Personnel**: Care is to be taken in the design and operation of RAS systems to minimise hazards to personnel who have to work in the vicinity of the RAS station. The likelihood of personnel being injured or knocked overboard by RAS equipment and operating gear is to be assessed and suitable guard rails are to be provided as necessary.

■ *Section 2* Principles

2.1 Design and operating principles

2.1.1 RAS systems are to be designed in accordance with user defined operating and performance criteria taking account of the ship type and service operating envelope.

2.1.2 RAS systems are to be capable of operation within specified operating conditions that include maximum sea states, wind conditions and those identified in *Vol 2, Pt 1, Ch 3, 4 Operating conditions*.

2.1.3 RAS systems are to be designed and installed such that degradation or failure of any RAS system will not render another system inoperable.

2.1.4 RAS systems are to be capable of operating within the normal vibration modes and cyclic loads of the ship.

2.1.5 RAS systems are to be designed to minimise the risks to ship, personnel and the environment. The risks involved in carrying out identified hazardous activities are to be as low as reasonably practicable.

2.2 Lifecycle principles

2.2.1 RAS systems are to be operated and maintained such that the required performance, integrity and dependability can be achieved throughout the life of the ship.

2.2.2 To demonstrate continued compliance with the Provisions of Classification for engineering systems, *see Vol 2, Pt 1, Ch 1, 2.1 Provisions 2.1.1*, surveys are to be carried out in accordance with the Regulations and as detailed in *Vol 3, Pt 1, Ch 5, 14 Survey through life*.

2.3 Class notations

2.3.1 Ships complying with the applicable requirements of this Chapter will be eligible for machinery class notations.

RAS(ABV)	Ships having arrangements to enable RAS operations astern, abeam and VERTREP.
RAS(AB)	Ships having arrangements to enable RAS operations abeam and astern only.
RAS(AV)	Ships having arrangements to enable RAS operations astern and VERTREP.
RAS(BV)	Ships having arrangements to enable RAS operations abeam and VERTREP.
RAS(A)	Ships having arrangements to enable RAS operations astern only.
RAS(B)	Ships having arrangements to enable RAS operations abeam only.
RAS(V)	Ships having arrangements to enable RAS operations VERTREP only.

2.3.2 Where ships comply with NATO replenishment at sea requirements, the requirements of this Chapter will be eligible for an additional character (**NT**) following any of the notations described in *Vol 3, Pt 1, Ch 5, 2.3 Class notations 2.3.1*. The relevant standard(s) (STANAG(s)) for assignment of the (**NT**) notation are to be specified with reference to the arrangements being applied from *Vol 3, Pt 1, Ch 5, 2.3 Class notations 2.3.1*. Assessment for compliance with the identified standard will address the safety and design/operating principles in these Rules.

■ *Section 3*
Acceptance criteria

3.1 General

3.1.1 The acceptance process will validate conformity of RAS systems and equipment to the provisions of classification for systems within the Ship Type category by assessing such systems for compliance with Lloyd's Register's (hereinafter referred to as 'LR') Rules and Regulations or their equivalent, and specified standards and codes.

3.1.2 The assessment process of RAS systems will consider all aspects of the system including ship to ship dynamic interaction and environmental effects.

3.1.3 Conformance with the performance criteria, together with any specific requirements of the applicable Rules, standards and legislation is to be demonstrated by the designer/Builder and Owner to the satisfaction of LR.

3.1.4 For RAS operations, the applicable Rules, Standards for classification are:

(a) LR *Rules and Regulations for the Classification of Naval Ships*.
(b) LR's *Code for Lifting Appliances in a Marine Environment*.
(c) Additional requirements of the Naval Administration, as specified.
(d) Owner specified requirements. These are to be identified before commencement of the design review or construction.
(e) Standards for transfer hoses.
(f) LR Type Approval System.
(g) LR Quality Scheme for Machinery.

Section 4
Design and construction

4.1 General

4.1.1 Documents relevant to the design, construction, installation, testing and operation of RAS systems are:

(a) LR's Rules for RAS systems.
(b) The equipment manufacturer's recommendations.
(c) NATO Replenishment at Sea documents where specified by the Owner.

4.1.2 The overall performance of RAS systems is to be demonstrated to conform to the performance criteria specified in the System Operational Concept.

4.2 Functionality

4.2.1 In general, NS1 and NS2 type ships are to be configured such that replenishment of solids and liquids can be conducted concurrently. Ships are to be capable of supplying and receiving RAS equipment such that they can transfer personnel by abeam replenishment. For abeam RAS operations, a minimum of four RAS stations (two port and two starboard) should be provided (for larger ships six RAS stations may be incorporated). For astern RAS operations, at least one station should be provided on the fo'c'sle for reception and on the aft deck for supply.

Section 5
Plans and particulars to be submitted

5.1 Plans and information

5.1.1 Three copies of the plans and information stated in *Vol 3, Pt 1, Ch 5, 5.1 Plans and information 5.1.2* are to be submitted to LR as applicable.

5.1.2 **System Operational Concept**. A System Operational Concept of the RAS systems that details the capability and functionality under defined operating and emergency conditions. The System Operational Concept is to be agreed between the designers and Owners and is to include as applicable:

(a) Required class notations.
(b) Details of intended supplying and receiving ships.
(c) Description of each RAS operation and combination of equipment required.
(d) Plans showing each proposed combination of equipment, fully rigged.
(e) Details of solids that may be received or supplied (maximum size and weight together with UN hazard category if applicable) together with transfer rates.
(f) Details of liquids that may be received or supplied, (including flash point of oils and transfer rates).
(g) Details of the range of ship's speeds, sea and environmental conditions under which each RAS operation may be undertaken.
(h) Interoperability capability.
(i) Manning requirements.
(j) Details of arrangements for RAS operations in darkness.
(k) Details of hose clearing/drainage arrangements after RAS operations have been completed, *see Vol 3, Pt 1, Ch 5, 9.1 General 9.1.4*.

5.1.3 **Engineering and safety justification**. An engineering and safety justification for the RAS systems stating design standards used, assumptions made and any technical evidence. The justification is to:

(a) State all design standards used for the design, manufacture, installation and testing of RAS systems and equipment.
(b) Provide details of all RAS equipment and compatibility of different items of equipment.

(c) Provide evidence that all RAS operations (equipment and combinations) at each RAS station as identified in the design statement, can be carried out safely and in accordance with classification and equipment manufacturer's requirements.
(d) Identify safe equipment configurations.
(e) Provide calculations that demonstrate that the structural loading is in accordance with Rule requirements.
(f) Provide calculations that demonstrate that equipment loads are in accordance with manufacturer's specified limits.
(g) Provide evidence that sufficient control, monitoring and communication facilities are provided to conduct RAS operations safely and efficiently.
(h) Limits are to be defined in terms of lateral separation between vessels, ship's speeds, wind force, sea conditions (wave height, period and direction) and environmental conditions (visibility). The validation of potential operational scenarios may be by using a set of generic ship types agreed between the Owner and the designer.
(i) Examine the effect of environmental conditions (e.g. sea state, water depth, visibility, wind strength, etc.) on the proposed RAS operations and define limiting conditions and define limiting environmental conditions for each RAS operation.
(j) Address the specific needs of emergency breakaway and demonstrate that such a procedure can be undertaken with all RAS equipment configurations at each RAS station. The recovery of equipment after an emergency breakaway is also to be addressed.
(k) Provide evidence that the ship internal, ship to ship and ship to helicopter communications systems will allow safe and efficient communications and RAS operations. The communications equipment and systems provided are to take into account the design of the ship and intended method of operation. Redundancy is also to be considered.
(l) Provide evidence that each system is designed to minimise the risks associated with handling the particular cargo (e.g. static electricity with aviation fuel).
(m) Address the disabling of automatic control, protection and safety functions for machinery and engineering systems where these are considered essential during replenishment at sea activities. The arrangements are to be consistent with the requirements of *Vol 2, Pt 1, Ch 3, 4.9 Military requirements 4.9.4*

Where applied standards are not in the public domain, e.g. ATP 16 (latest version) covering NATO Replenishment at Sea, a copy is to be included with the engineering and safety justification.

5.1.4 **General arrangement plan**. A general arrangement plan of the ship showing the following information:

(a) Position of each RAS station, with identifiable reference to the engineering and safety justification and System Operational Concept.
(b) The tasks to be carried out at each RAS station.
(c) Position of observation and control positions.
(d) Arcs of fields of view and operation from each of the observation and control positions and RAS stations.

5.1.5 **Structural plans**. Plans required by *Vol 1, Pt 4, Ch 1, 5 Military design requirements* and *Vol 1, Pt 4, Ch 2, 9 Military installation and operational loads*.

5.1.6 **Fluid transfer plans and particulars.**For the receiving ship, plans in diagrammatic form showing filling arrangements from the filling connection to filling trunks (where installed) and subsequently to each storage tank. The plans are to include a statement of the minimum flash point (closed-cup test) together with the required and the maximum transfer/filling rates. For the supplying ship, plans in diagrammatic form showing pumping and piping arrangements from storage tanks to the ship's discharge connection. *See also Vol 3, Pt 1, Ch 5, 9.1 General 9.1.10*.

5.1.7 **Lifting appliances.** Plans and details of all lifting appliances as required by LR's *Code for Lifting Appliances in a Marine Environment* or other specified design code.

5.1.8 **RAS equipment.** Details of equipment identified for RAS operations. Design and installation loads on the equipment together with details of securing and holding down arrangements. Details of the access required for maintenance and to operate the equipment.

5.1.9 **Operating manuals**. Operating manuals are to be provided on board and submitted for information where requested by LR. The manuals are to include the following information:

(a) Particulars and a description of each RAS system.
(b) Operating and maintenance instructions for all equipment.
(c) Matrix of safe combinations of equipment and details of permitted load that may be carried by each combination.
(d) Test procedures for each system.
(e) Details of valve and pipe configurations when transferring fluids.
(f) Details of arrangements for transfer of solids and personnel.

(g) Details of night operations.

5.1.10 **Testing and trials procedures**. A schedule of testing and trials to demonstrate that systems are capable of operating as described in the System Operational Concept. The testing and trials procedures are to include details of through life load testing which includes the periodicity of load testing for different items of equipment.

5.1.11 Where an evaluation of an engineering and safety justification is required for the propulsion and steering arrangements, *see Vol 3, Pt 1, Ch 5, 7.2 Machinery redundancy 7.2.2*, the following information is to be submitted:

(a) A Failure Modes and Effects Analysis (FMEA), *see Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*.
(b) Design standards and any assumptions made.
(c) Limiting operating parameters for ship and machinery installation.
(d) A statement and evidence in respect of the reliability of any non-duplicated components.

■ *Section 6*
Ship and arrangement requirements

6.1 Location of RAS stations and equipment

6.1.1 Designated RAS stations are to be provided for RAS operations. RAS stations are to be positioned on the Supplying Ship to maximise compatibility with Receiving Ships and such that, as far as possible, the effects of hull interaction between the Supplying and Receiving Ships are minimised. For some types of naval ships, a reception point for the replenishment of ammunition may be required on the fo'c'sle. The number, type and location of the RAS stations are to be agreed between the designer and Owner but as a guide, for NS1 and NS2 type ships, it is usual practice to have up to six abeam RAS stations (three on the port side and three on the starboard side) located symmetrically about the ship's centre line. *See also Vol 3, Pt 1, Ch 5, 4.2 Functionality 4.2.1*.

6.1.2 Each RAS station and the particular RAS operation(s) that may be carried out at the station is to be identified on the general arrangement plan.

6.1.3 Where possible on receiving ships, an abeam RAS station is to be located amidships to maximise crew protection during RAS operations during heavy weather conditions.

6.1.4 RAS stations are to be located so as to permit the observation of each RAS station from two observation positions. In general, the positions selected for the abeam RAS stations are to be port and starboard in the middle portion of the ship between 20 m and 40 m apart symmetrically positioned from amidships and set in so as to provide protection for the RAS crews in heavy seas.

6.1.5 Clear areas are to be provided at each RAS station. Sufficient clear area to enable safe and efficient operation of equipment is to be provided. The area available is to recognise the equipment manufacturer's recommendations for operations and is to be contained within 30º fore and aft of the normal transverse at the RAS station.

6.1.6 The location of all rigging securing points is to comply with the equipment manufacturer's requirements and agreed between the designer and Owner.

6.1.7 Clear and safe access to all rigging securing points is to be provided. Arrangements are to be provided to ensure that access to those securing points high on the superstructure can be reached safely and speedily. As far as practicable, the arrangements are to be such that there is no requirement for personnel to climb masts to gain access to RAS high points.

6.1.8 The access arrangements to all securing points are not to expose crew to dangerous electromagnetic hazards, *see Vol 2, Pt 1, Ch 3, 4.18 Electromagnetic hazards*.

6.1.9 In the selection and design of an abeam RAS position for a particular ship, for either a supply or receiving rig, the range of ships with which the ship can operate is to be considered so that the respective stations can be aligned transversely within ± 5º of the normal, without the amidships points of the receiving ship moving further forward than L/10 and L/5 aft of amidships of the supply ship, where L is the length of the supply ship.) *See Figure 5.6.1 Alignment of RAS stations*.

6.1.10 RAS stations are to be provided such that when two simultaneous RAS operations are being conducted, liquids can be transferred aft of solid cargo.

6.1.11 For requirements relating to electrical equipment for use in explosive gas atmospheres, *see Vol 2, Pt 9, Ch 5, 4 Electrical equipment for use in explosive gas atmospheres or in the presence of combustible dusts*.

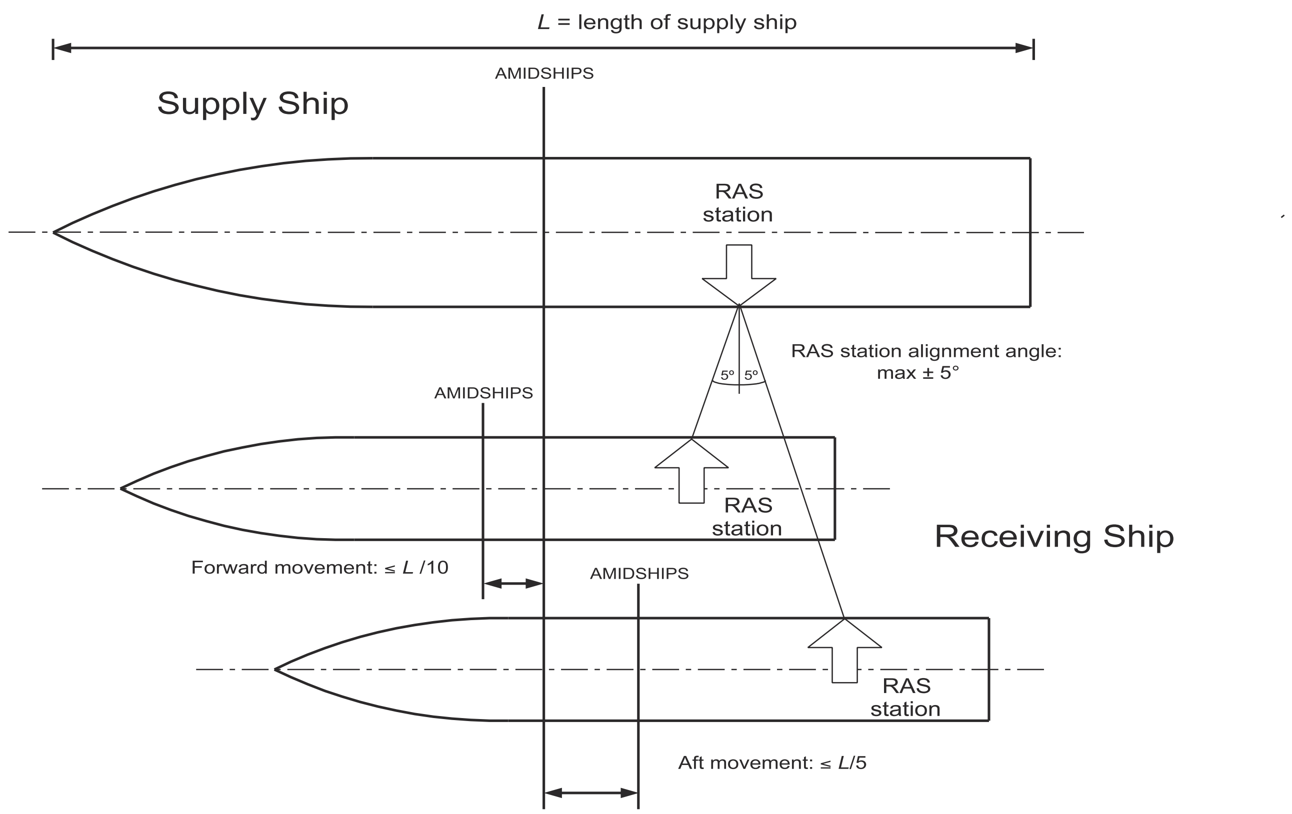


Figure 5.6.1 Alignment of RAS stations

6.2 RAS observation positions

6.2.1 Designated RAS observation positions are to be provided. Each observation position is to be sited to provide a clear field of view of all RAS operations at a particular RAS station. Each RAS station is to be capable of being observed from at least two observation positions.

6.2.2 Each RAS observation position is to be identified on the general arrangement plan. Arcs showing the field of view from each observation position are also to be shown on the general arrangement plan.

6.2.3 Safe access arrangements to each observation position are to be provided.

6.2.4 Each observation position is to be provided with:

(a) The necessary communication equipment to enable speedy and efficient communication to ensure safe RAS operations.
(b) Equipment to prevent personnel falling or being knocked overboard and a strong point for attachment of a harness arrangement.

6.3 RAS equipment store arrangements

6.3.1 Dedicated store arrangements are to be provided for the storage of RAS equipment and fittings. Stores are to be readily accessible from the weather deck and their respective RAS stations.

6.3.2 RAS equipment and fittings associated with potable fresh water RAS operations are to be provided with separate, clean, hygienic and secure conditions.

6.4 Position of radar units and other sources of electromagnetic energy

6.4.1 RAS stations, observation positions and securing points are as far as practicable to be sited clear of sources of electromagnetic energy such as radars, communication transmitters, or lightning conductors. Where such equipment or the swept beam from radar aerials is in close proximity to any RAS facilities, a Risk Assessment is to be undertaken, in accordance with *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*, to ensure that the dangers of RADHAZ are minimised.

6.5 Location and layout of stores

6.5.1 The number, type and location of stores are to be consistent with the routes leading to/from RAS stations. The layout of each store is to recognise the need to rapidly strike down equipment and provisions and is to be agreed between the designer and Owner.

6.5.2 The routes from RAS stations to stores are to be designed to simplify loading and movement of stores, equipment and provisions during RAS operations. The arrangements are to recognise minimising tripping hazards and the need for two people to pass without restriction.

6.5.3 The entrances to the interior of the ship from each RAS station are to be designed to prevent the ingress of sea-water when undertaking RAS operations in heavy weather conditions.

6.6 Ship's structure

6.6.1 Depending on the intended functional requirements of the ship, each RAS station that is designed to receive and/or supply solids during RAS operations is to have a designated dump area in the case of receiving ships and/or a dispatch area for supplying ships. The dump area is to be suitably stiffened and designed to withstand the impact loads that may arise whilst landing stores and equipment on board during RAS operations.

6.6.2 The extent of each dump area is to exceed the foot print of the largest pallet by not less than 1 metre in each direction. A factor of safety of not less than four times the maximum load to be transferred is to be used in the design of the structure.

6.6.3 The location of the dump area and/or dispatch area within the RAS station is to be agreed between the designer and Owner and is to centre on the high point where applicable.

6.6.4 For other structural requirements, *see Vol 1, Pt 4, Ch 2 Military Load Specification*.

6.7 Sources of high intensity noise

6.7.1 RAS stations, observation positions and securing points are to be sited such that exposure to high intensity noise (above 85 db) for personnel involved in RAS operations is as low as reasonably practicable.

■ *Section 7*
Ship operating system requirements

7.1 Bridge conning position

7.1.1 A conning location for the officer in charge of RAS operations is to be provided on the navigating bridge with a duplicated position on both bridge wings. The location is to be agreed between the designer and Owner and be included in the System Operational Concept.

7.1.2 From the conning position, the officer in charge is to be able to observe the ship’s heading and the relative movement of the two ships conducting RAS operations. Also, a gyro compass readout and rudder angle indicator are to be readily visible from the conning position.

7.1.3 Where specified an additional emergency conning position for use in the event of the bridge conning position being out of service may be required. The agreed location and arrangements are to be agreed between the designer and Owner and are to be specified in the System Operational Concept.

7.2 Machinery redundancy

7.2.1 The design of the propulsion and steering machinery is to provide arrangements that will permit RAS operations to be undertaken at minimum risk recognising a single failure in equipment associated with continuous propulsion and steering

capability. The requirements of the machinery class notation **PSMR** in *Vol 3, Pt 1, Ch 3 Propulsion and Steering Machinery Redundancy* are to be complied with as applicable. As a guide, ships are to be designed to be capable of maintaining continuous course and speed for at least one minute to facilitate safe emergency breakaway in the event of equipment failure in propulsion and steering systems.

7.2.2 Where ships are fitted with single screw propulsion and single rudder arrangements or having the additional **L** character assigned to a machinery redundancy notation, *see Vol 3, Pt 1, Ch 3 Propulsion and Steering Machinery Redundancy*, an evaluation of a detailed engineering and safety justification will be required, *see Vol 3, Pt 1, Ch 5, 5.1 Plans and information 5.1.11*. The evaluation process is to include the appraisal of a Risk Assessment (RA), in accordance with *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)*, to verify that sufficient levels of redundancy and monitoring are incorporated in the propulsion and steering systems to support effective manoeuvring control of the ship during RAS operations.

7.3 Seakeeping and manoeuvrability

7.3.1 The seakeeping and manoeuvrability characteristics of the ship are to be assessed and the requirements of the class notation **LMA** in *Vol 3, Pt 1, Ch 4 Manoeuvring Assessment* are to be complied with as applicable.

7.3.2 The controls for propulsion arrangements are to be designed to allow for small accurate changes in propulsion speed which may typically be 0,2 knot/propeller speed ± 2 rpm.

7.3.3 The steering gear arrangements that provide a speed of rudder movement required in *Vol 2, Pt 6, Ch 1, 4.1 General* are to be recognised in the assessment of the ship's manoeuvring capability. The speed of rudder movement may require to be increased for ships intended for RAS operations that may typically be 35° to 30° opposite helm in 14 seconds with all the steering gear power actuating systems operating.

7.4 Communications, signals and navigational aids

7.4.1 Arrangements for ship internal communications during RAS operations are to be provided. The communication equipment and systems are to be arranged to permit safe and effective communications throughout the RAS operations to all parties identified in the engineering and safety justification and the System Operational Concept.

7.4.2 As a minimum, means of effective ship internal communications are to be provided in accordance with *Table 5.7.1 Internal communications*. In addition, means of communications are to be provided for all those personnel involved with operation of equipment or movement of stores during RAS operations. For example, communications should be provided from the RAS station to:

(a) The operators of fuel system valves, who need to be advised promptly of the completion of RAS operations so that the fuel system may be reconfigured for normal running (unless valve operation is by remote control from the Master Filling Control Station).
(b) Those responsible for arranging for the supply and stowing the solid cargo who need to be appraised (quantity and type) of the stores en route and the completion of RAS operations.
(c) The replenishment control office where provided.

The communication equipment and systems provided are to take into account the design of the ship (e.g. the Master Filling Control Station may be located on the Bridge) and the intended method of operating the ship during RAS operations.

Table 5.7.1 Internal communications

Position	Conning position	RAS observation position	RAS equipment pontrol	Master filling control station	Notes
Conning position		+		+	
RAS station/VOA	+		+	+	*see* Note
RAS equipment control					
Master filling control station	+	+			
Note Each RAS station on the ship is to be capable of communication with the conning/command position, RAS Equipment Control station and the Master Filling Control station and the replenishment control office where provided.					

7.4.3 The design of internal communications equipment and systems is to provide sufficient redundancy such that in the event of a single equipment failure, RAS operations can proceed safely.

7.4.4 Ship to ship communication protocols and standards are to be specified and agreed between the designer and Owner.

7.4.5 Arrangements are to be provided to allow the crew accurately to determine the distance between the ships during RAS operations (e.g. use a distance line) on a continuous basis. Guard rails or suitable alternatives are to be provided for the safety of personnel in exposed upper deck positions. The arrangements and operational procedures are to be such that the crew of neighbouring ships will not be exposed to RADHAZ.

7.4.6 Means of visual and aural communication between the ships conducting RAS operations is to be provided.

7.4.7 If distance lines and sound-powered communication equipment, as specified by the Owner, are to be passed between the ships that are to undertake RAS operations, the following criteria are to be complied with:

(a) The positions of the communications equipment tie down/securing points and connections are to be agreed between the designer and Owner and shown on the RAS general arrangement plan.
(b) Distance line securing points are to be clear of all RAS stations and positioned so the distance line is readily visible from the RAS officer's conning position. The exact locations for securing the distance lines are to be agreed between the designer and Owner and shown on the RAS general arrangement plan.

7.4.8 The communication system requirements between receiving ship, delivery ship and helicopter during VERTREP operations are to be specified by the Owner.

7.5 RAS operations

7.5.1 The power supplies to weapons systems are to be arranged to permit partial isolation in accordance with ship operation procedures (including RADHAZ) and orders relating to RAS operations.

7.5.2 Facilities are to be provided at each RAS station to permit electrical grounding of RAS equipment and stores. VERTREP stations are to be provided with facilities and equipment to permit the discharge of static electricity from the helicopter and/or its underslung cargo whilst airborne.

7.5.3 RAS systems are to be designed and installed such that they do not degrade from defined criteria (for equipment and the ship) stemming from susceptibility to magnetic interference sources that may include military activities. Systems are to comply with the technical requirements of IEC 60533: *Electrical Installations in Ships, electromagnetic Compatibility*. Emission limits and immunity requirements are to be specified by the Owner where those specified in IEC 60533 are not appropriate for the ship type.

7.5.4 Facilities and equipment to undertake RAS operations in darkness are to be specified. Typically this will require provision of low intensity red lighting at each RAS station and on the routes to/from the RAS station to the stores and within the stores to allow safe operations in darkness. The arrangements are to be agreed between the designer and Owner and included in the System Operational Concept. Provision is also to be made for suitable low intensity lighting at control panels for operating RAS equipment.

■ *Section 8*
RAS station requirements

8.1 General

8.1.1 Each RAS station is to incorporate the features described in *Vol 3, Pt 1, Ch 5, 8.1 General 8.1.2*. *See Vol 3, Pt 1, Ch 5, 6.1 Location of RAS stations and equipment* for RAS station location and equipment requirements.

8.1.2 The design of RAS stations is to recognise the need to minimise the risks to personnel during RAS operations. Wherever possible RAS stations are to be designed for RAS operations to be carried out with guard rails in position; where this is not practicable, alternative arrangements for the safety of personnel are to be provided. Use is to be made of nonslip paint and tripping hazards are to be eliminated wherever possible.

8.1.3 Clear areas are to be provided at each abeam RAS station. Clear areas in the vertical direction are to be contained within 30° forward and aft of the normal transverse from each RAS station, *see Figure 5.8.1 Abeam RAS station clear areas*.

8.1.4 The clear areas for VERTREP operations are to be agreed between the designer and Owner. Reference is to be made to international standards for helicopter operations and the helicopter's capability requirements. The following are to be specified:

(a) Helicopter types.
(b) Underslung load earthing equipment/facilities.
(c) Range (size and weight) of cargo.
(d) Minimum clearance criteria.
(e) Lighting standards/requirements.
(f) Painting standards/requirements.
(g) Deck conductance for dissipation of static charge.

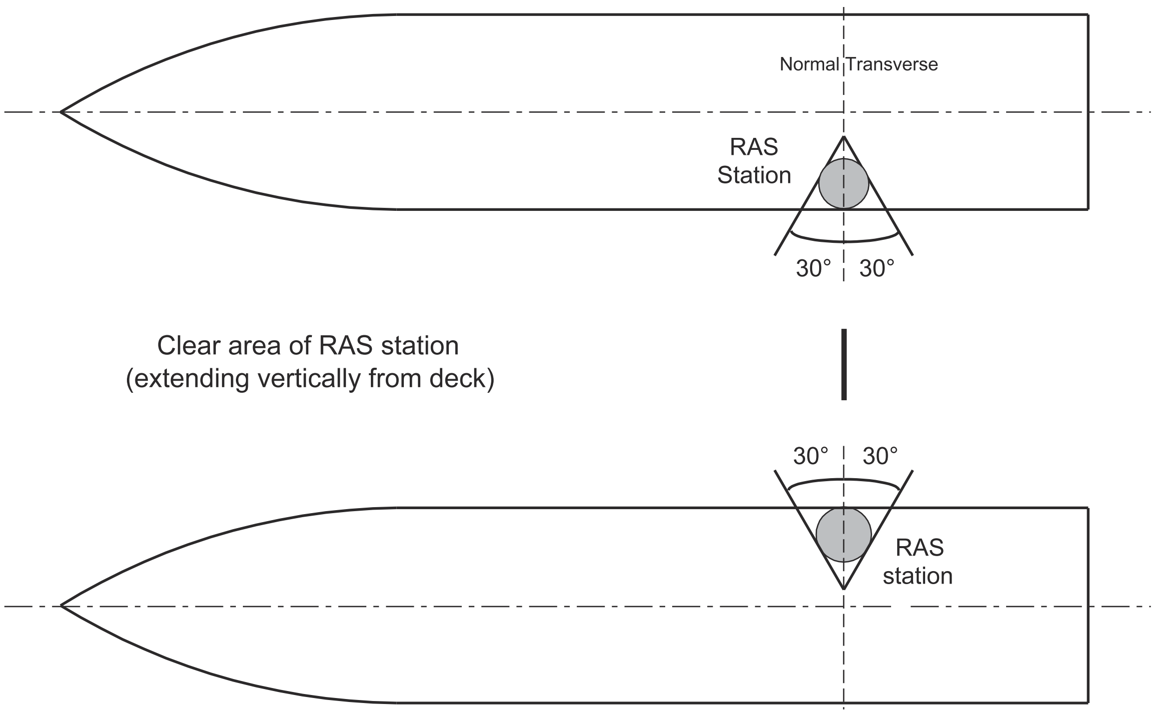


Figure 5.8.1 Abeam RAS station clear areas

8.1.5 The layout of each RAS station is to provide sufficient accessibility for attendance, operation and maintenance of RAS equipment and systems in accordance with the manufacturer's recommendations.

8.1.6 A minimum distance of 3 m between any RAS station superstructure and the edge of the weatherdeck is to be provided at each RAS station.

8.1.7 Where space allows, provision is to be made for the rigging of a safety wire to which life lines can be attached. Note, such lines are to be provided where the RAS station is designed for operations that require guard rails to be struck, *see Vol 3, Pt 1, Ch 5, 8.1 General 8.1.2*.

8.1.8 Communications equipment and facilities are to be provided at each RAS station, *see Vol 3, Pt 1, Ch 5, 7.1 Bridge conning position*.

8.1.9 Oil spill containment arrangements are to be provided at each RAS station at which fuel and/or oil is taken on board or supplied for both Supplying and Receiving Ships. These arrangements are to cater for small spills that may occur during hose handling and connection operations. Small quantities of fuel or oil that may be spilt are to be contained and be capable of being discharged to a safe location and not overboard. Attention is drawn to the requirements of the *International Convention for the Prevention of Pollution of the Sea by Oil, 1973/1978* and to any applicable Naval/National Regulations relating to the prevention of oil spills at sea and in harbour.

8.1.10 Where the Owner has specified military requirements relating to radar cross-section, the increased cross-section from exposed deck machinery and fittings is to be assessed with such equipment being recessed wherever practicable.

8.1.11 RAS high points for securing jackstays are to be located at least 3 m inboard of the deck edge and at the following recommended heights above deck level to ensure correct catenary of RAS equipment:

- 2,5 m for liquid transfer;
- 4,3 m for solids transfer.

8.2 RAS equipment control station

8.2.1 A dedicated RAS equipment control station is to be provided for all equipment at an RAS station.

8.2.2 Controls for RAS equipment that is to be operated sequentially as part of a system are to be grouped for control by a single operator wherever possible.

8.2.3 The RAS equipment control station is to be located so that the operator(s) has/have a clear view of all RAS equipment under their control.

8.2.4 The position of each RAS equipment control station is to be indicated on the general arrangement plan.

8.3 Emergency equipment

8.3.1 An RAS emergency equipment locker is to be provided and located near each RAS station. The locker is to contain all the emergency equipment and tools required to conduct emergency breakaway procedures for each RAS operation and equipment configuration. Emergency tools are to be provided in a man-portable container that can be placed to be ‘ready to hand’ during RAS operations. There are to be sufficient emergency tools or containers for at least two simultaneous RAS operations.

8.3.2 The tools in the emergency equipment locker are to be in accordance with the equipment manufacturer's recommendations.

■ *Section 9*
Transfer of liquids

9.1 General

9.1.1 Systems for the transfer of liquids are to be designed to minimise to as low as reasonably practicable the risks inherent with the RAS operational requirements for dealing with large quantities of fluids at high transfer rates.

9.1.2 The design of liquid transfer systems is to be such that it minimises danger to the ship, personnel and the environment.

9.1.3 Liquid transfer systems are to be designed to prevent over-pressurisation of transfer and filling lines and all associated storage tanks, and any relief valve fitted for this purpose is to discharge to an overflow tank or other safe position. The design of filling systems is to consider maximum filling rates, dynamic pressure drops and maximum static pressures of the storage tanks.

9.1.4 The design and arrangements of liquid transfer systems is to permit clearing/drainage/effective drainage of transfer hoses after RAS operations have been completed.

9.1.5 The arrangements for abeam transfer of fuel oil, lubricating oils, aviation fuel and fresh water are to be such that in the event of a single failure in a transfer system, this does not prevent transfer of these liquids, e.g. more than one RAS connection on each side of the ship and the ability to fill any tank from each RAS station from designated connections is to be provided.

9.1.6 Any storage tank overflow arrangements are to discharge to a safe position.

9.1.7 For requirements relating to water storage systems, *see Vol 2, Pt 11, Ch 1 Made and Fresh Water Systems*.

9.1.8 For requirements relating to aviation fuel storage systems, *see Vol 2, Pt 7, Ch 4 Aircraft/Helicopter/Vehicle Fuel Piping and Arrangements*.

9.1.9 For requirements relating to fuel oil storage systems, *see Vol 2, Pt 7, Ch 3 Machinery Piping Systems*.

9.1.10 For requirements relating to air, overflow and sounding systems, *see Vol 2, Pt 7, Ch 2, 10 Air, overflow and sounding pipes*.

9.1.11 For requirements relating to piping system design, *see Vol 2, Pt 7, Ch 1 Piping Design Requirements*.

9.1.12 For requirements relating to electromagnetic hazards, *see Vol 2, Pt 1, Ch 3, 4.18 Electromagnetic hazards*.

9.1.13 For requirements relating to control of static electricity, *see Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding* .

9.2 Filling and supply connections and arrangements

9.2.1 Filling and supply connections for liquid RAS operations are to be sited within the boundary of the RAS station. Fuel oil system risers are to terminate in the vicinity of the RAS dump area and are not to present a tripping hazard or impede the use of stores handling machinery. Each filling and supply connection is to be provided with an accessible isolating valve located in close proximity to its associated. *See also Vol 3, Pt 1, Ch 5, 9.2 Filling and supply connections and arrangements 9.2.14*.

9.2.2 As far as practicable, separate filling and supply connections are to be provided for each type of fluid that may be transferred. To reduce the risk of inadvertent incorrect hose connection, the filling and supply connections are to be of different types and separated as far as possible from each other and distinct for for each type of liquid to be transferred.

9.2.3 A strainer unit, capable of being cleaned and a means of sampling incoming liquids, is to be provided at each filling connection.

9.2.4 Each filling and supply connection is to be provided with a permanently attached notice identifying the fluid storage system(s) connected to the filling and supply connection(s).

9.2.5 Filling and supply connections and associated isolating valves are to be made from ductile materials. Where ships are required to operate in cold weather environments, materials of toughness greater than grade E are to be used.

9.2.6 Filling and supply connections are to be designed to allow an emergency breakaway to take place safely, speedily and with a minimum effort from the crew.

9.2.7 Filling and supply arrangements for flammable/hazardous liquids are to be designed to minimise the risk of static electricity build-up. The piping arrangements within storage tanks are to have outlet ends configured to reduce turbulence and foaming of the fuel. *See Vol 2, Pt 9, Ch 1, 2.4 Earthing and bonding* for requirements for control of static electricity.

9.2.8 The control of filling and supply operations for each system that can be used during RAS operations is to be capable of being carried out from a designated Master Filling/Supply Control Station. Designated Master Filling/Supply Control Stations are to be provided with:

(a) Effective communication equipment that permits communication with locations identified in the engineering and safety justification.
(b) Indication of tank high level and overflow alarms.
(c) Tank level/content indication.
(d) A clear visual means of ascertaining the valve configuration of each filling/supply system.

9.2.9 The arrangements for replenishment of fuel oil and aviation fuel are to cater for water-compensated tanks where these tanks are installed. *See Vol 2, Pt 7, Ch 3, 4.18 Water compensated fuel oil tanks*.

9.2.10 The pipes for lubricating oil and fresh water transfer systems are to be permanent to minimise the risk of contamination.

9.2.11 Lubricating oil and fresh water transfer/ filling arrangements are to be provided with a bulkhead filling connection positioned not less than 300 mm above the weatherdeck to minimise the risk of sea-water ingress into the system.

9.2.12 The arrangements for transferring lubricating oils are to be such that they permit the use of oil renovation systems whilst RAS operations are being carried out.

9.2.13 Filling and supply connection arrangements are to be designed as far as possible to reduce the incidence of, or opportunity for dissimilar metal corrosion.

9.2.14 Where ship design and arrangements permit, a dedicated compartment may be provided in close proximity to the RAS station which can be accessed from both port and starboard sides in which the commodity connection points, isolation valves and hoses are housed. This reduces the likelihood of dissimilar metal corrosion, negates the requirement for below deck isolating valves, flush deck fittings and reduces the upper deck clutter (radar cross-section) associated with stowing the hoses on the weather deck.

■ *Section 10* Transfer of solids

10.1 General

10.1.1 Solid cargo may be transferred during RAS operations using abeam and/or VERTREP procedures.

10.1.2 For ships intended for receiving solid supplies, the design of arrangements is to provide for rapid removal of cargo from the RAS station once received on board. The arrangements and equipment are to recognise the reception of large and/or heavy items of cargo and the number of crew required. A typical maximum transfer rate is 25 pallets (each pallet up to 2 tonnes) every hour in fair weather conditions. The design transfer rate is to be agreed between the Owner, designer and LR.

10.1.3 The removal routes for cargo and stores are to be clearly marked and shown on handling plans.

10.1.4 Equipment intended for transfer of solids is to be capable of handling the maximum size and weight of solids identified in the System Operational Concept.

10.1.5 For ships intended for supplying solid supplies, the design and arrangements is to provide for the safe and orderly transfer of solids to the RAS station consistent with safe working practices.

■ *Section 11* Transfer of personnel

11.1 General

11.1.1 Arrangements for the transfer of personnel are to be in accordance with a specified standard.

11.1.2 Unless specified, only manually powered equipment is to be installed for the transfer of personnel.

11.1.3 The design of arrangements for personnel is to provide sufficient space for the large numbers of crew normally required to operate the transfer equipment, typically 25 personnel to tension the rig on a receiving ship.

11.1.4 The mechanical devices used in the tensioning of any rigging and the transfer chair together with all transfer gear are to be of a proven safe design suitable for the purpose. The arrangements are to be such that when conducting a light jackstay transfer from a sliding pad-eye, the height of the pad-eye can be raised/lowered to facilitate the connecting/disconnecting process, but is to remain at a suitable fixed height during the actual transfer.

■ *Section 12* RAS equipment

12.1 General

12.1.1 The types of transfer that the ship is required to undertake are to be specified by the Owner and the selection of equipment is to be agreed between the designer and Owner.

12.1.2 It is the responsibility of the Builder to demonstrate the equipment is designed, manufactured, installed and tested in accordance with the applicable Rule requirements.

12.1.3 The selection of equipment is to address compatibility to provide for the correct rigging of equipment (blocks, shackle, etc) for the loads imposed, e.g. it should not be possible to use a light jackstay shackle with a heavy jackstay rig.

12.2 Emergency breakaway

12.2.1 All RAS equipment and facilities are to be designed to permit the application of emergency breakaway procedures that should normally be complete within one minute of the commencement of initiation. Use may be made of quick release couplings

and/or breakable couplings. Attention is to be given to the attachment of wires and ropes to winch drums and the selection of emergency breakaway equipment (wire cutters, axes, etc.).

12.3 Lifting devices

12.3.1 Winches are to incorporate safety features that permit safe RAS operations and cater for the unique loading conditions that may arise during RAS operations. The following features are to be considered:

(a) Service brake that permits quick and efficient engagement and disengagement by both automatic and manual means.
(b) Long-term brake that permits long term locking of the winch drum having manual engagement and disengagement only.
(c) An overload facility that prevents the wire/rope being overstressed during RAS operations (e.g. when ships move or roll apart).
(d) Spooling system that ensures proper spooling of the wire onto the drum.
(e) Anti-slack device that maintains tension in the wire when the winch is operating under no load.

12.3.2 Cranes, derricks and booms for RAS operations are to comply with LR's *Code for Lifting Appliances in a Marine Environment*.

12.4 Hoses and fittings

12.4.1 Hoses for transferring liquids are to be in accordance with standards applicable to the intended application.

12.4.2 Where probe fuelling systems are part of the design, the following features are to be incorporated:

(a) Automatic latching mechanism with sleeve valve that opens on proper engagement and automatically closes on disengagement.
(b) Disengagement on application of a specified load.
(c) Swivel arm that keeps probe receiver aligned with the spanwire.
(d) Manual release lever.
(e) Quick release hook.
(f) Indication of incorrect probe engagement.

■ *Section 13*
Testing and trials

13.1 General

13.1.1 Testing and trials are to be carried out to LR's satisfaction to demonstrate that systems and equipment operate and function as stated in the System Operational Concept.

13.1.2 Testing and marking of equipment is to be in accordance with Chapter 9 of LR's *Code for Lifting Appliances in Marine Environment* as applicable. Note that enhanced design factors of safety may be required with reference to handling and transfer of explosives and personnel, *see Vol 3, Pt 1, Ch 5, 1.3 Safety 1.3.1* and *Vol 3, Pt 1, Ch 5, 1.3 Safety 1.3.1*, and load testing will be required consistent with the system design requirements.

■ *Section 14*
Survey through life

14.1 General

14.1.1 RAS systems are subject to survey through life to a schedule that has been agreed to by LR. All systems and equipment forming part of the RAS installation are to be identified and included in a list of surveyable items.

14.1.2 Survey and testing of systems and equipment are to be in accordance with *Ch 9 Machinery* of LR's *Code for Lifting Appliances in a Marine Environment* as applicable. Note that enhanced design factors of safety may be required with reference to

handling and transfer of explosives and personnel, *see Vol 3, Pt 1, Ch 5, 1.3 Safety 1.3.1* and *Vol 3, Pt 1, Ch 5, 1.3 Safety 1.3.1*, and load testing will be required, consistent with the system design requirements.

14.1.3 The periodicity of load testing is to be in accordance with the testing and trials procedures required by *Vol 3, Pt 1, Ch 5, 5.1 Plans and information 5.1.10*. Load testing is to be carried out under the supervision of a competent person.

■ *Section 1* General

1.1 Application

1.1.1 The application of the additional requirements of this Chapter offers solutions for compliance with the buoyancy, stability and controllability performance requirements of Chapter III of ANEP-77 NATO Naval Ship Code (NSC) which have not already been addressed by application of the standard naval classification requirements. Where the optional requirements of this Chapter are applied, and it can be demonstrated that the vessel meets all of the performance requirements of the latest edition of the NSC Chapter III, a ship will be eligible to be assigned the **STAB** notation.

1.1.2 For compliance with the requirements of this Chapter the **RSA2** and **LMA** notations must also be assigned.

1.1.3 Where a loading instrument is provided on board the **LI** notation must be assigned.

1.1.4 Where a stability calculation program is provided, it is to be approved in accordance with Lloyd's Register's (hereinafter referred to as LR) *Approval of Longitudinal Strength and Stability Calculation Programs*. If it is the main source of verifying compliance with stability and buoyancy requirements for conditions outside the scope of the paper format examples provided then a duplicate back-up facility is to be provided on board.

1.1.5 A suitable subdivision and damaged stability standard, which complies with the performance requirements of Chapter III of the NSC, is to be specified, *see Vol 1, Pt 1, Ch 2, 1.1 Framework of Classification 1.1.9*.

1.1.6 A suitable intact stability standard which complies with the performance requirements of Chapter III of the NSC is to be specified, *see Vol 1, Pt 1, Ch 2, 1.1 Framework of Classification 1.1.9*.

1.1.7 Where the Owner requires specific extreme damage or extreme flooding events to be assessed, over and above the events inherent in the standards above, those extreme events are to be specified in the Concept of Operations (ConOps).

1.1.8 A sea-keeping analysis or model tests are to be undertaken, *see Vol 3, Pt 1, Ch 6, 2.4 Safety of embarked persons 2.4.1*. The range of environmental conditions used in the analysis or tests is to be consistent with the ConOps (e.g. specific headings for aircraft operations).

1.2 Documents required for design review

1.2.1 Information required to be submitted:

(a) Information regarding operation of the vessel:

- ConOps.
- Seakeeping analysis report or model test results.

(b) Information required to be submitted for approval:

- C11(N).
- Stability Information Book, *see Vol 3, Pt 1, Ch 6, 2.5 Provision of operational information 2.5.1*.

(c) Information regarding the ship's equipment:

- A register of essential life saving equipment.

1.2.2 Information required to be provided on board:

(a) Plans:

- Watertight and weathertight integrity plan.

(b) Instructions:

- Instructions covering the operation of watertight doors whilst at sea.

(c) Information:

- Register of safety points, *see Vol 3, Pt 1, Ch 6, 2.4 Safety of embarked persons 2.4.3*.
- Procedure for visual inspection of safety points by Responsible Persons.
- Record of Approved Safety Equipment.
- Approved Stability Information Book.
- Information covering ship operations in heavy weather and during manoeuvring, *see Vol 3, Pt 1, Ch 6, 2.5 Provision of operational information 2.5.2*.
- Dry-docking information, *see Vol 3, Pt 1, Ch 6, 2.5 Provision of operational information 2.5.3*.
- A log of visual inspection and testing of guard rails and handrails, *see Vol 3, Pt 1, Ch 6, 2.4 Safety of embarked persons 2.4.5*.

■ *Section 2* Requirements

2.1 Watertight integrity

2.1.1 Watertight doors below the level of watertight integrity are to comply with the requirements of *Vol 1, Pt 3, Ch 4, 4 Watertight doors and hatches in watertight subdivision boundaries* and *Vol 2, Pt 9, Ch 9, 5.9 Watertight doors 5.9.1*. An additional requirement over and above the requirements of *Vol 2, Pt 9, Ch 9, 5.9 Watertight doors 5.9.1* is that there is to be no single point of failure in the door control system or power operating system. For this purpose an FMEA or other satisfactory means of demonstrating compliance is to be submitted.

2.1.2 Watertight doors are to indicate to a manned central control station and other control stations as required by the Naval Administration.

2.1.3 Watertight doors are to be clearly marked in accordance with the procedure specified in *Vol 3, Pt 1, Ch 6, 1.2 Documents required for design review 1.2.2*, stating that the appropriate authority is to be sought prior to operation of the door.

2.1.4 All main watertight subdivision compartments are to be fitted with means of water ingress detection. Water ingress is to be indicated at all main control stations and a suitable audible alarm is to be provided. The number and location of flooding detection sensors is to be sufficient to ensure that any substantial water ingress into a main subdivision compartment is detected under reasonable angles of trim and heel.

2.2 Reserve of buoyancy

2.2.1 LR will verify compliance with the agreed subdivision and damaged stability standard. Where alternative arrangements or non-compliances with the agreed standard occur, they are to be recorded in the tailoring document, *see Vol 1, Pt 1, Ch 2, 3.2 Tailoring – Departures from the Rules and Rule additions*.

2.2.2 The definitions of damage for the assessment of the **RSA2** notation are to include damages which are consistent with the compartment damage criteria specified by the subdivision and damaged stability standard, *see Vol 1, Pt 4, Ch 2 Military Load Specification*.

2.3 Reserve of stability

2.3.1 LR will verify compliance with the agreed intact stability standard. Where alternative arrangements or non-compliances with the agreed standard occur they are to be recorded in the tailoring document, *see Vol 1, Pt 1, Ch 2, 3.2 Tailoring – Departures from the Rules and Rule additions*.

2.4 Safety of embarked persons

2.4.1 The results of the sea-keeping analysis or model test are to demonstrate that the predicted RMS motions, deck wetness, Motion Induced Interruptions (MII) and Motion Sickness Incidences (MSI) for the design are within the limits specified in STANAG 4154 or another specified standard. Values are to be predicted or recorded at the following locations as a minimum, where applicable:

- Navigation bridge.
- Machinery control room.

- Flight deck.
- RAS operating positions.
- Well-deck.

2.4.2 Work stations are to be fitted with suitable arrangements, e.g. handholds/seatbelts/harnesses to enable the crew to perform their duties when adverse ship motions occur. The fittings and their supporting arrangements are to be to the Surveyor's satisfaction.

2.4.3 Where safety points for attaching harnesses are provided on board they are to be selected from, and installed in accordance with, an appropriate standard (e.g. BS EN 795). A Register of safety points is to be produced at build and maintained in service. A procedure for the visual inspection of safety points by a Responsible Person is to be developed and confirmed as being implemented. As a minimum the procedure is to:

- Define the standard or applicable legalisation which is used to define a Responsible Person;
- Nominate an appropriate Responsible Person or persons;
- Detail any training which the Responsible Person is to receive;
- Detail any qualifications which the Responsible Person is to hold;
- State that safety points are to be inspected by a Responsible Person at least every 12 months;
- Mandate that a record is kept of when each safety point was last inspected and by whom;
- Authorise the Responsible Person to request that the safety point be load tested in accordance with the applicable standard;
- Authorise the Responsible Person to remove the item from service should they consider it appropriate to do so.

2.4.4 Guard rails, handrails and safety points are to be visually inspected and tested through life at intervals specified by the Naval Administration. The tests are to be undertaken by a Responsible Person in accordance with an appropriate standard agreed with the Naval Administration.

2.4.5 A log of visual inspections and testing is to be maintained on board the vessel and updated by the Responsible Person. Where guard rails, handrails or safety points are found to be deficient, the deficiency is to be reported to the appropriate maintainer. At Annual Survey the Surveyor is to satisfy themself that the visual inspection and testing is being undertaken and that the log is being updated appropriately.

2.5 Provision of operational information

2.5.1 A Stability Information Book is to be provided on board containing the following information:

(a) The stability standard or requirements;
(b) General precautions against capsize;
(c) Loading and operating restrictions;
(d) Cross-flooding arrangements [if fitted];
(e) Verification of compliance with the stability standard;
(f) Trim and draught limitations;
(g) Free surface effects;
(h) Payload heeling effects;
(i) Loading and unloading precautions;
(j) Securing arrangements;
(k) Control of openings;
(l) Loll;
(m) Hull strength;
(n) Stability or loading computer [if fitted];
(o) Non sailing conditions [if applicable];
(p) Particulars of the ship;
(q) Details of the lightship and its derivation;
(r) Details of hydrostatics and cross curves of stability;
(s) Capacity and centroid of tanks, stores and cargo spaces plus other payload data;
(t) Example calculations of stability;
(u) Example ship conditions compliant with stability requirements;
(v) Damage stability information demonstrating ship survivability following foreseeable, extreme and catastrophic damage; and

(w) Methods to recover margins of buoyancy and stability.

2.5.2 Information regarding ship operations in heavy weather or during manoeuvres shall be provided on board.

The information shall contain as a minimum:

(a) The risk of broaching;
(b) The shipping of green seas;
(c) Slamming;
(d) Heel in turn characteristics;
(e) The impact of motions on the safety of the crew and essential safety functions;
(f) Practices or methods specific to the vessel to reduce the impact of motions on the safety of the crew and equipment;
(g) The effects of squat and manoeuvring in shallow water;
(h) The effects of wind on manoeuvring; and
(i) The minimum manoeuvring speed.

2.5.3 Information on dry-docking the ship shall be provided on board. The information provided shall be consistent with *Vol 1, Pt 3, Ch 5, 10.4 Dry-docking loads* and contain as a minimum:

(a) The location of dock blocks and lightship weight distribution;
(b) The location of discharges, shore connections and appendages; and
(c) Information for maintaining stability throughout the drydocking process.

Noise and Vibration Levels in Personnel Spaces

■ *Section 1* General requirements

1.1 Scope

1.1.1 These Rules set down the criteria for the assessment of noise and vibration levels on naval ships and are applied in addition to the other relevant requirements of the *Rules and Regulations for the Classification of Naval Ships* (hereinafter referred to as the Rules for Naval Ships).

1.1.2 These Rules apply to surface ships when engaged in peace-time mission profiles.

1.1.3 These Rules provide for two alternatives:

(a) A **Certificate of Compliance** which records that the ship has been designed and built to meet the noise and vibration criteria contained in these Rules. This is to be confirmed by measurements during an Initial Survey, or

(b) A **Class Notation**, which in addition to the provisions of *Vol 3, Pt 2, Ch 1, 1.1 Scope 1.1.3*, requires periodic survey of the noise and vibration characteristics throughout the life of the ship.

1.1.4 For self-propelled ships below 200 tonnes static lightship displacement, higher noise and vibration levels will be permitted. Limits for these ships are identified within the text of these Rules.

1.1.5 These Rules recognise existing national and international Standards and specify levels of noise and vibration currently achievable using good engineering practice. Compliance with these requirements will be assessed by review of procedures, inspection and measurement of the relevant parameters. Pre-survey reviews, inspections and measurements will be conducted, witnessed or assessed by Lloyd's Register (hereinafter referred to as 'LR') Surveyors. All vessels can apply for Acceptance Numerals 1 and 2.

1.1.6 These Rules present values of noise and vibration which should be verified by measurements following completion of the ship. It is recommended that the builders undertake calculations of noise and vibration so that any potential problem areas can be identified and control measures implemented.

1.1.7 The sound pressure levels for audible alarms and public address systems fitted in accordance with other Sections of the Rules are to satisfy IMO Resolution A.1021(19) *Code on Alerts and Indicators, 2009* or other specified arrangements.

1.2 Definitions

1.2.1 **Crew and embarked personnel spaces** are defined as all areas intended for crew and embarked personnel use, and include the following:

(a) Accommodation spaces (e.g. cabins, corridors, offices, mess rooms, recreation rooms).

(b) Work spaces.

(c) Navigation spaces.

1.2.2 **Noise level** is defined as the A-weighted sound pressure level measured in accordance with ISO 2923.

1.2.3 **Vibration level** is defined as the single amplitude peak value of deck structure vibration during a period of steady-state vibration, representative of maximum repetitive behaviour, in mm/s peak, over the frequency range 1 to 100 Hz.

1.3 Certificate of Compliance

1.3.1 The Certificate of Compliance provides ship operators with an objective assessment of a ship's noise and vibration levels in accommodation spaces at the time of the assessment.

1.3.2 The Certificate of Compliance is optional and if requested, however, any ship can be assessed for compliance, using these requirements as a basis for the assessment.

1.3.3 To achieve the Certificate of Compliance, *Vol 3, Pt 2, Ch 1, 2 Noise* and *Vol 3, Pt 2, Ch 1, 7.1 Initial Survey* must be complied with.

1.3.4 The Certificate of Compliance will be issued after the Initial Survey, following satisfactory assessment of the measured data.

1.4 Class notations

1.4.1 The notations provide ship operators with an objective assessment of a ship's noise and vibration levels in accommodation spaces throughout its life.

1.4.2 The **CEPAC** (Crew and Embarked Personnel Accommodation Comfort) notation is optional.

1.4.3 For ships classed with LR which achieve the comfort standards specified in these Rules, the class notation **CEPAC** will be assigned. Following the **CEPAC** notation, numerals **1** or **2** will indicate the acceptance criteria to which the noise and vibration levels have been assessed.

1.4.4 The **CEPAC** notation indicates that the crew and embarked personnel accommodation and work areas meet the acceptance criteria.

1.4.5 To achieve and maintain any of the foregoing notations, *Vol 3, Pt 2, Ch 1, 2 Noise* must be complied with.

■ *Section 2* Noise

2.1 Maximum noise levels

2.1.1 Where the measured noise level exceeds the applied noise limit, the noise rating (NR) number is to be established in accordance with ISO 1999. If the NR number minus 5 dB(A) does not exceed the noise limit the requirement is fulfilled.

2.1.2 Guidance on maximum acceptable sound pressure levels and noise exposure limits is given in IMO *Resolution MSC. 337(91) – Adoption of the Code on Noise Levels on Board Ships – (Adopted on 30 November 2012)The Annex below is consolidated into Noise Levels - Code on Noise Levels on Board Ships (Resolution MSC.337(91))*.

2.2 Crew and embarked personnel accommodation and work areas

2.2.1 When the ship is proceeding in its normal operating condition and in accordance with the provisions specified in *Vol 3, Pt 2, Ch 1, 4.2 Test conditions*, the noise levels specified in *Table 1.2.1 Accommodation - maximum noise levels, in dB(A)* and *Table 1.2.2 Work areas - Maximum noise levels* are not to be exceeded.

Table 1.2.1 Accommodation - maximum noise levels, in dB(A)

Location	Ships greater than 200 tonnes lightship		Ships less than 200 tonnes lightship	
	Acceptance numeral			
	1	2	1	2
Sleeping cabins, hospitals	52	60	55	60
Day cabins, offices, conference rooms	55	65	60	65
Mess rooms	57	65	60	65
Open deck work areas	67	75	72	75
Alleyways, changing rooms, bathrooms, lockers	70	75	75	75
Note The levels may be exceeded by 5 dB(A) within 3 m of a ventilation inlet/outlet or machinery intake/uptake on open decks.				

Table 1.2.2 Work areas - Maximum noise levels

Location	dB(A) level
Machinery space (continuously manned)	90
Machinery space (not continuously manned) e.g. pump, refrigeration, thrusters or fan rooms	110
Workshops and non-specified work spaces	85
Machinery control rooms	75
Wheelhouse, conning positions and operational control rooms	65
Look-out posts e.g. at bridge wing or window	70
Additional limits:	
—250 Hz band —5000 Hz band	68 63
(measured according to IMO A.343(IX))	
Radio rooms	60
Galleys and pantries:	
Equipment not working Individual items at 1 m	75 85
Normally unoccupied spaces (e.g. holds, decks)	90
Ship's whistle, on bridge wings or forecastle	110

2.3 Acoustic insulation

2.3.1 Acoustic insulation of bulkheads and decks between crew spaces is to be in accordance with the requirements of IMO *Resolution MSC.337(91) – Adoption of the Code on Noise Levels on Board Ships – (Adopted on 30 November 2012)The Annex below is consolidated into Noise Levels - Code on Noise Levels on Board Ships (Resolution MSC.337(91))*

2.4 General alarm and crew and embarked personnel address systems

2.4.1 The general alarm and crew and embarked personnel address systems are to comply with *Vol 3, Pt 2, Ch 1, 2.4 General alarm and crew and embarked personnel address systems 2.4.2* and *Vol 3, Pt 2, Ch 1, 2.4 General alarm and crew and embarked personnel address systems 2.4.3* together with *Vol 2, Pt 9 Electrotechnical Systems* and *Vol 2, Pt 9, Ch 10, 4.1 Crew and embarked personnel address system*.

2.4.2 During the noise measurement programme the general alarm and crew address systems are to be demonstrated by tests. These tests are to be undertaken under the sea trial conditions as described in *Vol 3, Pt 2, Ch 1, 4.2 Test conditions*.

2.4.3 When the ship is underway in normal conditions, the minimum sound pressure levels of the public address system for broadcasting emergency announcements are to comply with the following:

(a) In interior spaces:

- 75 dB(A), and
- at least 20 dB(A) above the speech interference level.

(b) In exterior spaces:

- 80 dB(A), and
- at least 15 dB(A) above the speech interference level.

NOTE

The speech interference level is defined as the arithmetic average of the sound pressure level of the ambient noise in the four octave bands: 500 Hz, 1000 Hz, 2000 Hz and 4000 Hz.

Section 3
Vibration

3.1 Maximum vibration levels

3.1.1 Vibration limits are given in units of:

(a) peak acceleration (mm/s^2), single amplitude, in the range 1 to 5 Hz; and
(b) peak velocities (mm/s), single amplitude, in the range 5 to 100 Hz.

3.1.2 Measured vibration levels are to be assessed over the frequency range 1 to 100 Hz. The limits apply to each single frequency component of vertical, fore and aft and athwartship vibration which are to be assessed separately.

3.1.3 Crew and embarked personnel spaces are to be assessed with the ship proceeding in its normal condition and in accordance with the provisions set out in *Vol 3, Pt 2, Ch 1, 4 Testing*. The vibration levels specified in *Table 1.3.1 Ships greater than 200 tonnes lightship. Accommodation - maximum vibration levels*, *Table 1.3.2 Ships greater than 200 tonnes lightship. Work areas - maximum vibration levels*, *Table 1.3.3 Ships less than 200 tonnes lightship. Accommodation - maximum vibration levels* and *Table 1.3.4 Ships less than 200 tonnes lightship. Work areas - maximum vibration levels* are not to be exceeded.

Table 1.3.1 Ships greater than 200 tonnes lightship. Accommodation - maximum vibration levels

Location	1 to 5 Hz		5 to 100 Hz	
	Peak acceleration mm/s^2		Peak velocity mm/s	
	Acceptance numeral			
	1	2	1	2
Sleeping cabins, hospitals	126	157	4	5
Day cabins, offices, conference rooms, mess rooms	157	189	5	6
Open deck areas	157	189	5	6
Alleyways, changing rooms, bathrooms, lockers	157	189	5	6

Table 1.3.2 Ships greater than 200 tonnes lightship. Work areas - maximum vibration levels

Location	1 to 5 Hz		5 to 100 Hz	
	Peak acceleration mm/s^2		Peak velocity mm/s	
	Acceptance numeral			
	1	2	1	2
Machinery spaces (continuously manned) and stores	157	189	5	6
Machinery spaces (not continuously manned) e.g. pump, refrigeration, thruster or fan rooms	157	189	5	6
Workshops and aircraft hangars	157	189	5	6
Machinery control rooms	126	157	4	5
Wheelhouse and conning positions	126	157	4	5
Bridge wings	126	157	4	5
Command, control and communication compartments	157	189	5	6
Galleys and pantries	157	189	5	6
Normally unoccupied spaces	157	189	5	6

Table 1.3.3 Ships less than 200 tonnes lightship. Accommodation - maximum vibration levels

Location	1 to 5 Hz		5 to 100 Hz	
	Peak acceleration mm/s^2		Peak velocity mm/s	
	Acceptance numeral			
	1	2	1	2
Sleeping cabins, hospitals	157	189	4	6
Day cabins, offices, conference rooms, mess rooms	189	220	6	7

Open deck areas	189	220	6	7
Alleyways, changing rooms, bathrooms, lockers	189	220	6	7

Table 1.3.4 Ships less than 200 tonnes lightship. Work areas - maximum vibration levels

Location	1 to 5 Hz		5 to 100 Hz	
	Peak acceleration mm/s^2		Peak velocity mm/s	
	Acceptance numeral			
	1	2	1	2
Machinery spaces (continuously manned) and stores	189	220	6	7
Machinery spaces (not continuously manned) e.g. pump, refrigeration, thruster or fan rooms	189	220	6	7
Workshops and aircraft hangars	189	220	6	7
Machinery control rooms	157	189	5	6
Wheelhouse and conning positions	157	189	5	6
Bridge wings	157	189	5	6
Command, control and communication compartments	189	220	6	7
Galleys and pantries	189	220	6	7
Normally unoccupied spaces	189	220	6	7

■ *Section 4* Testing

4.1 Measurement procedures

4.1.1 These requirements take precedence where quoted standards may differ.

4.1.2 The trial measurements may be undertaken by an approved technical organisation or by LR. In the former case, the measurements shall be witnessed by an LR Surveyor.

4.2 Test conditions

4.2.1 Test conditions for the surveys are to be in accordance with those detailed in ISO 2923 and ISO 6954:2000.

4.2.2 The intended operating conditions of the ship during assessment surveys are to be submitted to LR for agreement, prior to commencement of surveys.

4.2.3 Surveys will only be conducted when the ship is fully outfitted and all systems contributing to noise and vibration levels are fully operational.

4.2.4 The test conditions required for the vibration and noise measurements are to be in accordance with the following conditions:

(a) Propulsion machinery operating profiles are to be submitted prior to the trials and a respective service condition agreed between the Owner and LR. Noise and vibration measurements will be taken at this service condition and the acceptance numeral assigned. In addition, noise and vibration measurements will be required at a condition where the power absorbed

by the propeller(s) is not less than 85 per cent of the maximum continuous rating of the propulsion machinery. At this condition, the maximum noise and vibration levels relating to acceptance number 2 must not be exceeded.

(b) All propulsion and auxiliary machinery, including HVAC systems, are to be running in their normal sea-going mode during the noise and vibration trials. Combinations of auxiliary machinery operation may be necessary.

(c) Measurements are to be taken with the ship proceeding ahead, at a constant speed and course, in a depth of water not less than five times the draught of the ship.

(d) Trials are to be conducted in sea conditions not greater than sea state 3 on the WMO sea state code.

(e) The ship is to be at a displacement and trim corresponding to the normal operating condition.

(f) Rudder angle variations are to be limited to ±2° of the midship position and rudder movements are to be kept to a minimum throughout the measurement periods.

(g) In addition, for ships which are designed to spend a considerable period of time in harbour, the noise and vibration levels are to be measured for this condition, with the auxiliary machinery and HVAC systems running at their normal rated capacity.

(h) Care is needed to ensure that external sources of noise, due to aircraft for example, do not influence the noise measurement results.

4.2.5 Prior to survey, a test programme is to be submitted for approval by LR. This programme is to contain details of the following:

(a) Measurement locations, indicated on a general arrangement of the ship.

(b) The ship’s outfit condition during survey.

(c) The machinery operating condition, including HVAC system, during survey.

(d) Noise and vibration measuring equipment.

4.3 Noise measurements

4.3.1 Noise measurements are to be conducted in accordance with ISO 2923 and IMO *Resolution MSC.337(91) – Adoption of the Code on Noise Levels on Board Ships – (Adopted on 30 November 2012)The Annex below is consolidated into Noise Levels - Code on Noise Levels on Board Ships (Resolution MSC.337(91))*. Measurements of noise levels are to be carried out using precision grade sound level meters conforming to IEC 60651, Type 1 or 2. Subject to demonstration, equivalent standards are acceptable.

4.3.2 Where the measured noise exceeds the relevant criteria, or contains subjectively annoying low frequency noise, or obvious tonal components, octave band readings are to be taken, with centre frequencies from 31,5 Hz to 8 kHz.

4.3.3 Measurements are to be performed to evaluate the ship with respect to sound insulation, the measurement locations and quantity are to be agreed with LR.

4.4 Noise measurement locations

4.4.1 Measurement locations are to be chosen so that assessment represents the overall noise environment on board the ship. At least 50 percent of the sleeping accommodation areas are to be surveyed. Distribution of the measurement locations is to be agreed by LR.

4.4.2 During measurement trials, recognised noise sources are to be operated at their normal level of noise output (e.g. machinery at design rating).

4.5 Vibration measurements

4.5.1 Vibration measurements are to be conducted in accordance with ISO 6954:2000.

4.5.2 Measurements are to be made with an electronic system capable of providing vibration frequency spectra in the range 1 to 100 Hz.

4.6 Vibration measurement locations

4.6.1 Measurement locations are to be chosen so that the assessment represents the overall vibration environment onboard the ship. To minimise survey times, readings may be taken at the locations previously defined for the noise assessment part of the survey.

4.6.2 In cabins, vibration readings are to be taken in the centre of the floor area. The measurements are to indicate the vibration of the deck structure. In large spaces, such as mess rooms, sufficient measurements are required to define the vibration profile.

4.6.3 Where deck coverings make transducer attachment impracticable, use of a small steel plate having a mass of at least 1 kg is permissible.

4.6.4 At all locations, vibrations in the vertical direction are to be assessed. Sufficient measurements in the athwartships and fore and aft directions are to be taken to define global vibrations.

■ *Section 5* Survey reporting

5.1 General

5.1.1 The survey report is to comprise the data and analysis for both noise and vibration and is to be submitted to LR for consideration.

5.1.2 The survey report shall be prepared by the organisation undertaking the trial measurements, which is to be either LR of an approved technical organisation or approved by LR.

5.2 Noise

5.2.1 The reporting of results is to comply with ISO 2923 and IMO *Resolution MSC.337(91) – Adoption of the Code on Noise Levels on Board Ships – (Adopted on 30 November 2012)The Annex below is consolidated into Noise Levels - Code on Noise Levels on Board Ships (Resolution MSC.337(91))*, and is to include:

(a) The results of public address and general alarm system testing, in addition to the acoustic insulation testing.
(b) Measurement locations indicated on a general arrangement plan including, where possible, the measured dB(A) level.
(c) Tabulated dB(A) noise levels, together with octave band analysis for positions where the level exceeds the specified criterion. The NR number is also to be given where octave band analyses have been conducted. If the NR number minus 5 dB(A) does not exceed the noise limit the requirement is fulfilled.
(d) Ship and machinery details.
(e) Trial details:

- Loading condition.
- Machinery operating condition.
- Speed.
- Average water depth under keel.
- Weather conditions.
- Sea state.

(f) Details of measuring and analysis equipment (e.g. manufacturer, type and serial numbers), including frequency analysis parameters (e.g. averaging time).
(g) Copies of the relevant instrument calibration certificates, together with the results of field calibration checks.

5.3 Vibration

5.3.1 The report is to contain the following information:

(a) Measurement positions indicated on a general arrangement plan.
(b) The maximum peak vibration levels and their corresponding frequencies taken from the frequency spectra, tabulated for all measurement locations.
(c) Ship and machinery details.
(d) Trial details:

- Loading condition.
- Machinery operating condition.
- Speed.
- Average water depth under keel.
- Weather conditions.
- Sea state.

(e) Details of measuring and analysis equipment (e.g. manufacturer, type and serial number), including frequency analysis parameters (e.g. resolution, averaging time and window function).

(f) Copies of the relevant instrument calibration certificates, together with the results of field calibration checks.

■ *Section 6* Excessive noise and vibration

6.1 Noise excesses

6.1.1 Noise levels greater than those specified in these Rules may be considered. Not more than 20 per cent of the accommodation cabins are to exceed the relevant noise criteria by more than 3 dB(A)

6.2 Vibration excesses

6.2.1 Vibration levels greater than those specified in these Rules may be considered. Not more than 20 per cent of all accommodation cabins are to exceed the relevant vibration criteria by more than 0,3 mm/s.

■ *Section 7* Survey requirements

7.1 Initial Survey

7.1.1 The Initial Survey shall comprise sea trial or initial in-service testing, reporting and assessment against the criteria set out in these Rules.

7.1.2 The sea trial or initial in-service testing requirements are set out in *Vol 3, Pt 2, Ch 1, 4 Testing*, and are to be reported in accordance with *Vol 3, Pt 2, Ch 1, 5 Survey reporting* and evaluated against the requirements of *Vol 3, Pt 2, Ch 1, 2 Noise* and *Vol 3, Pt 2, Ch 1, 3 Vibration*.

7.2 Periodical Survey (first 6 years)

7.2.1 An Annual Survey is to be held between 9 and 15 months after the completion of the Initial Survey. Measurements of noise and vibration will be required at a minimum of 25 per cent of the locations specified for the Initial Survey. The locations are to be submitted to LR for agreement, prior to commencement of the Annual Survey.

7.2.2 An Intermediate Survey is to be held within three months before or after the third anniversary of completion of the Initial Survey. The percentage of measurements required is to be as specified in *Vol 3, Pt 2, Ch 1, 7.2 Periodical Survey (first 6 years) 7.2.1*.

7.2.3 If the limiting criteria as described in *Vol 3, Pt 2, Ch 1, 6.1 Noise excesses* and *Vol 3, Pt 2, Ch 1, 6.2 Vibration excesses* are exceeded and the cause of the exceedance cannot be rectified at the time of the survey, then a Renewal Survey may be required.

7.3 Periodical Surveys (subsequent years)

7.3.1 A Renewal Survey is to be held at six-yearly intervals, the first one six years from the completion of the Initial Survey. The measurements required shall be the same as those required for the Initial Survey.

7.3.2 Following each Renewal Survey, an Intermediate Survey is to be held between the second and third subsequent years. The percentage of measurements required is to be as specified in *Vol 3, Pt 2, Ch 1, 7.2 Periodical Survey (first 6 years) 7.2.1*.

7.4 Surveys following modifications

7.4.1 A Renewal Survey may be required following modifications, alterations or repairs including replacement of major machinery items. It is the responsibility of the Owner to advise LR of such modifications.

Section 8
Referenced standards

8.1 Noise

8.1.1 The following National and International Standards for noise are referred to in these Rules:

- ISO 2923, *Acoustics – Measurement of noise on board vessels*.
- ISO 1999, *Acoustics – Determination of occupational noise exposure and estimation of noise-induced hearing impairment*.
- ISO 717/1, *Acoustics – Rating of sound insulation in buildings and of building elements;* Part 1: *Airborne sound insulation*.
- IMO *Resolution MSC.337(91) – Adoption of the Code on Noise Levels on Board Ships – (Adopted on 30 November 2012)The Annex below is consolidated into Noise Levels - Code on Noise Levels on Board Ships (Resolution MSC.337(91))*.
- IEC Publication 651, *Sound level meters*.
- ISO 140/4, *Acoustics – Measurement of sound insulation in buildings and of building elements;* Part 4: *Field measurements of airborne sound insulation between rooms.*

8.2 Vibration

8.2.1 The following National and International Standards for vibration are referred to in these Rules:

- ISO 6954:2000, *Mechanical vibration – Guidelines for the measurement, reporting and evaluation of vibration with regard to habitability on passenger and merchant ships*.

Section 1
General requirements

1.1 Application

1.1.1 This Chapter contains requirements for the control of operational pollution on naval ships.

1.1.2 Compliance with this Chapter is optional. A ship meeting the requirements of this Chapter will be eligible for an appropriate class notation, which will be recorded in the *Register Book*.

1.1.3 LR is to be advised of any matter that relates to the environmental performance of the ship that would affect the assignment of the **ENV** class notation.

1.1.4 It is a prerequisite for assignment of the **ENV** notation that the ship is classed with LR, and as a minimum the requirements for achieving **POL(I,AFS)** are to be complied with.

1.2 ENV class notation

1.2.1 **ENV** notation is assigned when the requirements for one or more of the following characters are complied with:

A	Anti-fouling coatings;
BWT	Ballast water treatment;
GW	Grey water and sewage;
IHM	Inventory of Hazardous Materials (ship recycling);
NOx-1, NOx-2, NOx-3	Emissions of nitrogen oxides;
OW	Oily water management;
P	Oil tanks in protected locations;
RS	Refrigeration Systems;
SOx	Emissions of sulphur oxides.

1.3 Documentation required for design review

1.3.1 When an alteration or addition to the approved arrangements and procedures is proposed, appropriate details are to be submitted for approval.

1.4 In-service records

1.4.1 Records demonstrating the effective implementation of the operational procedures specified in *Vol 3, Pt 2, Ch 2, 2 ENV characters*, as applicable, are to be maintained.

1.4.2 These records are to be kept on board for a minimum period of three years, in a readily accessible form, and are to be available for inspection by LR Surveyors, as required.

■ *Section 2* ENV characters

2.1 Anti-fouling coatings – A character

2.1.1 For assignment of the **A** character, the anti-fouling system applied to the ship's hull is to be listed as biocide-free in the Lloyd's Register List of Approved Products.

2.1.2 The following plans and documents are to be submitted:

AFS Certificate or equivalent.

2.2 Ballast Water Treatment – BWT character

2.2.1 For the assignment of the **BWT** character the following requirements are to be met.

2.2.2 A ballast water management treatment system is to be installed, utilised and approved in accordance with *Resolution MEPC.174(58) – Guidelines for Approval of Ballast Water Management Systems (G8) – (Adopted on 10 October 2008)*.

2.2.3 A ballast water management plan, in accordance with the Guidelines for the Development of Ballast Water Management Plans included within *Resolution MEPC.127(53) - Guidelines for Ballast Water Management and Development of Ballast Water Management Plans (G4) - (Adopted on 22 July 2005)* and approved by LR, shall be on board and effectively implemented.

2.2.4 A ballast water record book for the purpose of recording all ballast water operations and use of the treatment system is to be available on board and maintained.

2.2.5 The requirements for the safe integration of BWT systems are included in *Vol 2, Pt 7, Ch 2, 11 Ballast System* of the Naval Ship Rules.

2.2.6 The following plans and documents are to be submitted:

(a) Approved ballast water management plan;
(b) Ballast water treatment system manual and drawings showing the ballast water treatment system arrangements;
(c) IMO Type Approval certificate for the installed ballast water treatment system.

2.3 Grey water and sewage – GW character

2.3.1 For assignment of the **GW** character where a plant for the treatment of grey water is installed, the plant discharge effluent is to meet the standards specified in *Vol 3, Pt 2, Ch 2, 2.3 Grey water and sewage – GW character 2.3.2* or *Vol 3, Pt 2, Ch 2, 2.3 Grey water and sewage – GW character 2.3.4*, as applicable. The **GW** character will also be assigned where grey water is retained on board in dedicated holding tank(s) for discharge ashore, subject to the requirements specified in *Vol 3, Pt 2, Ch 2, 2.3 Grey water and sewage – GW character 2.3.5* being met.

2.3.2 The capacity of the sewage treatment system is to be sufficient for the maximum number of persons on board. The minimum capacity is to be 15 litres/day/person for black water and 135 litres/day/person for grey water.

2.3.3 Where it is not intended that the effluent be recycled or re-used for any purpose, the effluent of the grey water treatment plant is to meet the following standards:

(a) Thermotolerant coliforms:

The geometric mean of the thermotolerant coliform count of samples of effluent taken during a test period is not to exceed 100 thermotolerant coliforms/100 ml as determined by membrane filter, multiple tube fermentation or an equivalent analytical procedure.

(b) Total suspended solids:

- Where the equipment is tested on shore, the geometric mean of the total suspended solids content of the samples of effluent taken during the test period is not to exceed 35 mg/l;
- Where the equipment is tested on board the ship, the geometric mean of the total suspended solids content of the samples of effluent taken during the test period is not to exceed the suspended solids content of the ambient (flushing) water used on board plus 35 mg/l.

The method of testing is to be as given in *Resolution MEPC.159(55) - Revised Guidelines on Implementation of Effluent Standards and Performance Tests for Sewage Treatment Plants - (Adopted on 13 October 2006)*.

(c) Biochemical Oxygen Demand (BOD5) and chemical oxygen demand (COD):

- The geometric mean of a 5-day Biochemical Oxygen Demand (BOD5) is not to exceed 25 mg/l. The chemical oxygen demand (COD) is not to exceed 125 mg/l. Test methods are to be ISO 15705:2002 for COD and ISO 5815-1:2003 for carbonaceous BOD5 or other internationally accepted equivalent test standards.

(d) pH: the pH of the samples of effluent taken during the test period is to be between 6 and 8,5.

(e) Zero or non-detected values: for thermotolerant coliforms, zero values are to be replaced with a value of 1 thermotolerant coliform/100 ml to allow the calculation of the geometric mean. For total suspended solids, BOD5 and COD values below the limit of detection are to be replaced with one half the limit of detection to allow the calculation of the geometric mean.

2.3.4 Where it is intended that the effluent of the grey water treatment plant be re-used or recycled for any purpose, the effluent is to meet the potable water quality standards of the Naval Administration.

2.3.5 As an alternative to treatment, where grey water is retained on board in dedicated holding tank(s) for discharge ashore, the holding tank(s) is to be of adequate capacity, taking into account the operation of the ship, the number of persons on board and other relevant factors. Each tank is to be fitted with a means to open the tank, means to verify visually the contents of the tank and a high level alarm.

2.3.6 Means are to be provided to aerate the tanks to prevent the development of anaerobic conditions, taking into account *MSC/Circular.648 – Guidelines for the Operation, Inspection and Maintenance of Ship Sewage Systems – (Adopted on 6 June 1994)* .

2.3.7 Ventilation pipes from the grey water treatment system and, where provided, from holding tank(s) are to be independent of other ventilation systems.

2.3.8 A suitable piping system from the grey water treatment system or holding tank(s) is to be provided to allow discharge to shore reception facilities. The discharge pipe is to terminate with a standard discharge connection complying with the requirements of *Regulation 10 - Standard Discharge Connections*. Any connection from the grey water system to the sewage discharge is to be via a screw-down non-return valve.

2.3.9 Records of grey water treatment and/or discharge are to be maintained. A single record book may be utilised for both grey water and sewage records. Records detailing discharges from the holding tank(s) are to include:

(a) the date, location and quantity of grey water discharged from the holding tank(s) either ashore or at sea;
(b) rate of discharge of untreated grey water;
(c) distance from land and ship's speed, when untreated grey water is discharged to sea.

2.3.10 Procedures for the cleaning and safe entry of grey water treatment systems and holding tanks, including the use of suitable personal protective equipment, are to be provided and implemented.

2.3.11 The following plans and documents are to be submitted:

(a) Drawings showing the grey water and sewage system arrangements;
(b) Treatment system manual and documentation demonstrating that the grey water system meets the requirements for thermotolerant coliforms, total suspended solids, biochemical oxygen demand, chemical oxygen demand, and pH (if treatment system fitted);
(c) Document showing the grey water holding tank is of adequate capacity.

2.4 Inventory of hazardous materials – IHM character

2.4.1 For assignment of the **IHM** character, the ship is to possess an inventory of hazardous materials in compliance with Regulation 5 of the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships.

2.4.2 The inventory is to be independently verified by LR.

2.4.3 Procedures covering maintenance of the inventory of hazardous materials throughout the ship's life are to be established and implemented. The procedures are to address, *inter alia*, new installations containing hazardous materials specified in appendices 1 and 2 of the Hong Kong International Convention for the Safe and Environmentally Sound Recycling of Ships and relevant changes in the ship's structure and equipment.

2.4.4 The following plans and documents are to be submitted:

(a) Inventory of hazardous materials certificate of compliance;

(b) Procedures for maintaining the inventory of hazardous materials.

2.5 Emissions of nitrogen oxides – NOx-1, NOx-2, NOx-3 characters

2.5.1 For assignment of the **NOx-1** or **NOx-2** character, the total weighted value of NO_x emissions from all installed diesel engines defined within *Vol 3, Pt 2, Ch 2, 2.2 Ballast Water Treatment – BWT character 2.2.1* is not to exceed 80 per cent of the total weighted NO_x emission limits specified in *Regulation 13 – Nitrogen Oxides (NOx)*.

2.5.2 The total weighted emission value for the ship (*WV*) is to be calculated as follows:

$$WV_{[\text{ship}]} = \frac{WAEV_{[\text{cert}]}}{WAEV_{\{\text{IMO}\}}}$$

where

$$WAEV_{[\text{cert}]} = \frac{\Sigma \quad {}^{\text{n}}{}_{\text{n}\,=\,1}\left(\text{NO}_{\text{x[cert]}}\text{P}\right)}{\Sigma \quad {}^{\text{n}}{}_{\text{n}\,=\,1}(P)}$$

$$WAEV_{[\text{IMO}]} = \frac{\Sigma \quad {}^{\text{n}}{}_{\text{n}\,=\,1}\left(\text{NO}_{\text{x[IMO]}}\text{P}\right)}{\Sigma \quad {}^{\text{n}}{}_{\text{n}\,=\,1}(P)}$$

n = the number of individual engines on board the ship

P = the rated power, in kW, of each individual installed engine

$NO_{x[cert]}$ = the certified NO_x emission value, in g/kWh, for each individual engine

$NO_{x[IMO]}$ = the NO_x emission limit value, in g/kWh, of each individual engine, in g/kWh, applicable at the date of construction of the ship, or installation date of the engine, as applicable, as specified in *Regulation 13 – Nitrogen Oxides (NOx)* of Annex VI to MARPOL.

2.5.3 For ships constructed before 1 January 2011, the **NOx1** character will be assigned when:

$$\frac{WAEV_{[\text{cert}]}}{WAEV_{\{\text{IMO}\}}} \leq 0,8$$

For ships constructed on or after 1 January 2011, the **NOx2** character will be assigned when:

$$\frac{WAEV_{[\text{cert}]}}{WAEV_{\{\text{IMO}\}}} \leq 0,8$$

2.5.4 For assignment of the **NOx-3** character, all installed diesel engines with an individual output power greater than 130 kW, other than those used solely for emergency purposes, and associated NO_x emission abatement systems are to be certified as meeting the Tier 3 NO_x emission limits specified in *Regulation 13 – Nitrogen Oxides (NOx)*.

2.5.5 Equipment and systems used to control NO_x emission levels are to:

(a) be arranged so that failure will not prevent continued safe operation of the engine;
(b) be operated in accordance with manufacturer’s instructions;
(c) be designed, constructed and installed to ensure structure integrity and freedom from significant vibration;
(d) be designed to include adequate hatches for inspection and maintenance purposes; and
(e) be instrumented to record operation. Records of operation and the degree of control are to be maintained.

Alternative control arrangements will be given special consideration.

2.5.6 Procedures covering the use and maintenance of the equipment and systems used to control NO_x are to be established and implemented. Records are to be maintained which demonstrate the operation of the equipment and systems and the resultant level of NO_x emissions to the atmosphere.

2.5.7 Where engines constructed before 1 January 2000 are not certified in accordance with *Annex VI - Regulations for the Prevention of Air Pollution from Ships*, the test procedures and measurement method are to be in accordance with the Simplified Measurement Method or Direct Measurement and Monitoring Method given in Chapter 6 of the NO_x Technical Code.

2.5.8 In the case where the individual engines are ‘family’ or ’group’ engines, as defined in the NO_x Technical Code, the respective certified emission value is to be taken as that of the relevant Parent Engine.

2.5.9 The following plans and documents are to be submitted:

(a) For supplementary characters **NOx-1** and **NOx-2**:

Technical documentation to demonstrate that the total weighted value of NO_X emissions from all installed diesel engines (excluding emergency generator and engines with an individual power output of less than 130 kW) does not exceed 80 per cent of the applicable *Annex V of MARPOL 73/78Regulations for the Prevention of Pollution by Garbage from Ships* limits;

(b) For supplementary character **NOx-3**:

Technical documentation, including certification, to demonstrate all diesel engines (excluding emergency generator and engines with an individual power output of less than 130 kW) comply with *Annex VI - Regulations for the Prevention of Air Pollution from Ships* Tier III limits.

2.6 Oily bilge water, OW character

2.6.1 For assignment of the **OW** character, the loading or discharge connections and vent pipes/overflows associated with fuel oils, lubricating oils, hydraulic oils and other oils are to be fitted with drip trays. Drip trays fitted to loading or discharge connections are to be fitted with closed drainage systems except on tankers, where alternative arrangements will be considered.

2.6.2 Fuel oil storage, settling and service tanks are to be fitted with high level alarms and/or acceptable overflow systems.

2.6.3 Procedures covering the handling of all oils and oily wastes are to be established and implemented. As a minimum, these are to cover:

(a) loading, storage and transfer of fuel oils, lubricants, hydraulic oil, thermal heating oil and drummed oil products;
(b) storage, transfer, discharge and disposal of oily mixtures contained in the bilge holding and waste oil tanks and machinery space bilges;
(c) recovery of any oil spilled on decks.

2.6.4 All drainage from machinery space bilges is to be discharged ashore, except under exceptional circumstances.

2.6.5 Adequate capacity for storage of oily bilge water between discharges ashore is to be provided.

2.6.6 As an alternative to discharging bilges ashore, discharge to sea is permitted where it can be demonstrated that the oil-on-water content of the water discharged is less than 5 ppm. In this case, the bilge alarm, set at 5 ppm, is to be recalibrated or retested every five years by the manufacturer, or other acceptable alternative, and full records of the recalibration or retesting are to be kept on board.

2.6.7 Full records of all oily water discharges to shore and to sea are to be kept.

2.6.8 The following plans and documents are to be submitted:

(a) Drawings showing the arrangements of non-cargo oil loading and discharge connections, and tank vent pipes/overflows associated with fuel oils, together with associated drip trays and drainage systems;
(b) Drawings showing the fuel oil storage, settling and service tank high level alarms/overflow systems;
(c) Drawings showing the bilge holding, waste oil and sludge tank capacities and piping arrangements;
(d) Oil spill prevention procedures including list of equipment provided for the collection and recovery of spilled oil;
(e) Explanation of the provision that has been made for storage of oily bilge water (for ships that discharge oily water ashore);
(f) Type approval certificate for the oily water separator (for ships that discharge oily water to sea).

2.7 Oil tanks in protected locations, P character

2.7.1 For the assignment of the **P** character, all fuel oil tanks, lubricating oil tanks and hydraulic oil tanks are to be located in a protected location away from the ship's side or bottom shell plating.

2.7.2 The location of tanks is to be in accordance with the requirements relating to fuel oil tank protection given in *Regulation 12A – Oil fuel tank protection*.

2.7.3 Main engine lubricating oil drain tanks and fuel overflow tanks are excluded.

2.7.4 Arrangements providing equivalent protection will be given special consideration.

2.7.5 Suction wells may protrude below fuel oil tanks provided they are as small as possible and the distance between the tank bottom and the ship's bottom shell plating is not reduced by more than 50 per cent.

2.7.6 The following plans and documents are to be submitted:

- Drawings showing the arrangement of fuel oil, lubricating oil and hydraulic oil tanks and associated suction wells.

2.8 Refrigeration systems, RS character

2.8.1 These requirements apply to all permanently installed refrigeration and air-conditioning installations on board. These requirements do not apply to stand-alone refrigerators, freezers and ice makers used in galleys, pantries, bars and crew accommodation.

2.8.2 The use of chlorofluorocarbons (CFCs) in existing, and hydrochlorofluorocarbons (HCFCs) in new, refrigeration or air-conditioning installations is prohibited.

2.8.3 If halocarbon refrigerants are used, they are to have an Ozone Depleting Potential (ODP) rating of zero and a Global Warming Potential (GWP) of less than 1950, based on a 100-year time horizon.

2.8.4 Systems are to be arranged with suitable means of isolation so that maintenance, servicing or repair work may be undertaken without releasing the refrigerant charge into the atmosphere. Unavoidable minimal releases are acceptable when using recovery units.

2.8.5 For the purposes of refrigerant recovery, the compressors are to be capable of evacuating a system charge into a liquid receiver. Additionally, recovery units are to be provided to evacuate a system either into the existing liquid receiver or into cylinders dedicated to this purpose. The number of cylinders is to be sufficient to contain the complete charge between points of isolation in the system.

2.8.6 Where different refrigerants are in use they are not to be mixed during evacuation of systems.

2.8.7 Refrigerant leakage is to be minimised by leak prevention and periodic leak detection procedures. The frequency of leak detection and the maximum allowable annual leakage rate is dependent on the charge of each system and is specified in *Table 2.2.1 Refrigerant leak testing - Maximum perodicity*.

Table 2.2.1 Refrigerant leak testing - Maximum perodicity

Charge size	Periodicity	Leakage
under 3 kg	6 months	10%
3–30 kg	3 months	10%
30–300 kg	Monthly	5%
Over 300 kg	Monthly	3%

2.8.8 Records are to be maintained demonstrating that leak testing is carried out, in accordance with the periodicity specified in *Table 2.2.1 Refrigerant leak testing - Maximum perodicity*, by qualified personnel holding relevant certification, using either direct or indirect measuring methods and calibrated instruments where applicable.

2.8.9 A leak detection system appropriate to the refrigerant is to be provided to monitor continuously the spaces into which the refrigerant could leak. An alarm is to be activated to give warning in a permanently manned location when the concentration of refrigerant in the space exceeds a predetermined limit (25 ppm for ammonia, 300 ppm for halogenated fluorocarbons). Remedial measures to repair the leakage are to be implemented as soon as practicable after an alarm is activated. Each leak detection system is to be checked at least once every 12 months to ensure proper functionality. The system is to be maintained and calibrated in accordance with the manufacturer's recommendations and recorded in the log book.

2.8.10 Procedures for refrigerant management, including adding and recovering refrigerant charge, leak detection and the means adopted to control the loss and leakage of refrigerants, are to be established and implemented.

2.8.11 Refrigerant inventory and log book records are to be maintained, covering:

(a) Refrigerant added to each system.
(b) Refrigerant leaks, including remedial actions.
(c) Refrigerant recovered and storage location.
(d) Refrigerant disposal including quantity and location.
(e) Details of personnel suitably experienced or with an applicable qualification for maintenance of the onboard refrigerant system(s), including relevant certification.

2.8.12 After a leak has been identified, repaired and recorded, it is to be rechecked prior to the system entering normal service. All applications, independent of charge size, are to be checked for leakage within one month after a leak has been repaired to ensure that the repair remains effective.

2.8.13 Records demonstrating the implementation of the operational procedures specified in *Vol 3, Pt 2, Ch 2, 2.8 Refrigeration systems, RS character 2.8.16*, as applicable, are to be maintained. These records are to be kept on board for a minimum period of three years, in a readily accessible form, and are to be available for inspection by LR Surveyors, as required.

2.8.14 A refrigerant log book is to be maintained for the lifetime of the system. It must record the quantity and type of refrigerant installed and the quantities added and recovered during servicing, maintenance and final disposal.

2.8.15 All personnel involved in the following activities must be suitably experienced or possess an applicable qualification:

(a) installation, servicing or maintenance of the refrigeration equipment covered by the **ECO** Notation;
(b) checking such equipment for any leakages of refrigerant gases; or
(c) repairing, or carrying out work to prevent, such leakages.

2.8.16 The following plans and documents are to be submitted:

(a) Details and location of each permanently installed refrigeration system. Mass of refrigerant charge in each system and the refrigerant designation (e.g. R-134a);
(b) Refrigeration plant general arrangement drawing showing the number and location of refrigerant leak detectors;
(c) Sample refrigerant leak testing record book;
(d) Refrigerant plant general arrangement drawing showing the number and location of leak detectors;
(e) Operational procedure for refrigerant management including adding and recovering refrigerant charge, leak detection and sample log book;
(f) Sample refrigerant inventory and log book.

2.9 Emissions of sulphur oxides, SOx character

2.9.1 For assignment of the **SOx** character, all fuel used on board is to be:

(a) distillate with a sulphur content not exceeding 0,10 per cent m/m; or
(b) an alternative fuel or a hybrid fuel management solution which has a resulting sulphur content which is not to exceed 0,10 per cent sulphur m/m.

2.9.2 A fuel oil management system is to detail the maximum sulphur content to be specified when ordering fuel oils and the means adopted to verify that the sulphur content of fuel oils supplied meets that requirement.

2.9.3 Where testing to determine the sulphur content of fuel received on board is to be carried out, a representative sample is to be drawn at the time of delivery from the ship's bunker manifold using the manual or automatic sampling methods defined in ISO 3170 or 3171, or their national respective equivalents. Fuel sulphur content is to be subsequently determined using the laboratory test method ISO 8754:2003: *Determination of sulphur content – Energydispersive X-ray fluorescence spectrometry*.

2.9.4 The following plans and documents are to be submitted:

- Bunker specification that will be used to purchase fuel for the ship.

■ *Section 3* Survey requirements

3.1 Initial Survey and Audit

3.1.1 Following satisfactory review of the plans and other information submitted, an ENV Initial Survey is to be undertaken for ships under construction or in service.

3.1.2 At the ENV Initial Survey, the Surveyor is to be satisfied that the requirements of these Rules are complied with. The Surveyor is to verify that the hull and machinery arrangements are in accordance with the approved documentation. The installed equipment, together with associated control and alarm systems, is to be demonstrated under working conditions.

3.1.3 Following the successful completion of the Initial Survey, the **ENV** notation may be assigned to a ship. The **ENV** notation will be valid, in the first instance, for a period not exceeding 12 months. During this period, an audit of the procedures as required by these Rules is to be undertaken. This audit is to be performed after the procedures have been fully implemented, subjected to internal audit and have generated at least 3 months of records under in-service conditions.

3.1.4 Audits are to confirm by direct observation, examination of internal audit reports and scrutiny of records that each of the procedures have been implemented effectively over the preceding period. It is also to be verified that:

(a) the required resources and equipment have been provided; and
(b) the ship's staff are aware of their duties and responsibilities, and can perform the assigned tasks.

3.2 Periodical Surveys and Audits

3.2.1 ENV Annual Surveys are to be held on all ships to which the **ENV** notation applies within three months of each anniversary for assignment of the **ENV** notation.

3.2.2 At the ENV Annual Survey, the Surveyor is to be satisfied that the arrangements and equipment comply with these Rules. As far as possible, the installed equipment, together with associated control and alarm systems, are to be demonstrated under working conditions.

Additionally:

(a) where changes to arrangements or equipment fitted to meet the requirements of these Rules have been made, it is to be verified that these changes are in accordance with approved documentation; and
(b) records for the preceding 12 months are to be reviewed.

3.2.3 ENV Audits are to be undertaken in accordance with the requirements given in *Vol 3, Pt 2, Ch 2, 3.1 Initial Survey and Audit 3.1.4*.

3.2.4 Where the Periodical Surveys and audits are not completed in accordance with *Vol 3, Pt 2, Ch 2, 3.2 Periodical Surveys and Audits 3.2.1* the **ENV** notation will be suspended. Reinstatement will be subject to surveys being held appropriate to the age of the ships and the circumstances of the case.

3.3 Change of Naval Administration

3.3.1 Where the Naval Administration changes, the **ENV** notation will be suspended.

3.3.2 The new Naval Administration may adopt the previously approved procedures as required by these Rules or may compile new procedures which would need to be submitted for approval.

3.3.3 Following implementation of the approved procedures, an audit, in accordance with the requirements in *Vol 3, Pt 2, Ch 2, 3.1 Initial Survey and Audit 3.1.3* and *Vol 3, Pt 2, Ch 2, 3.1 Initial Survey and Audit 3.1.4*, is to be undertaken.

3.3.4 The **ENV** notation will be re-assigned following successful completion of the audit provided that the requirements are complied with.

■ *Section 1*
General requirements

1.1 General

1.1.1 This Chapter states the requirements for ships having centralised refrigeration systems, designed to reject heat from provision refrigerated stores and are in addition to the relevant requirements of the *Rules and Regulations for the Classification of Naval Ships* (hereinafter referred to as the Rules for Naval Ships) contained in Volumes 1 and 2.

1.1.2 The requirements, which are optional, cover arrangements, equipment, and systems necessary for effective provision refrigerated stores arrangements on board a naval ship.

1.1.3 Ships complying with the applicable requirements of this Chapter will be eligible for the optional machinery class notation **PRM** (Provision Refrigeration Machinery).

1.2 Documentation required for design review

1.2.1 Three copies of the plans and information stated in *Vol 3, Pt 2, Ch 3, 1.2 Documentation required for design review 1.2.2* are to be submitted to Lloyd's Register (hereinafter referred to as 'LR') as applicable.

1.2.2 **System Design Description.** A System Design Description, *see Vol 3, Pt 1, Ch 3, 3.5 Fuel oil storage and transfer systems* of the refrigeration system(s) that details system capability and functionality under defined operating and emergency conditions within the normal concept of operation role of the ship. The arrangements for refrigerated stores for the ship are to be agreed between the designer and the Owner and are to be specified in the System Design Description.

1.2.3 **Systems**. Plans in diagrammatic form showing refrigerant and cooling systems, control systems and safeguards and electrical systems covered by this Chapter. Plans are to show pipe sizes, flows and terminal locations. The capacities of fans and pumps are to be included. Capacity tables for different operating conditions for the refrigeration compressors are also to be included.

1.2.4 **Compartments**. Plans showing the general arrangement of refrigeration plant compartments, together with a description of the equipment and arrangements installed for isolation and distribution of ventilation air and the electrical power supply systems. The plans are to indicate segregation and access arrangements for compartments and associated control rooms/ stations.

1.2.5 **Testing and trials procedures**. A schedule of testing and trials to demonstrate that systems are capable of operating as described in *Vol 3, Pt 2, Ch 3, 3 Refrigerating machinery and refrigerant storage compartment arrangements* and as required by *Vol 3, Pt 2, Ch 3, 7 Testing and trials*.

1.2.6 **Operating manuals**. Operating manuals are to be provided on board and submitted for information where requested by LR. The manuals are to include the following information:

(a) Particulars and a description of the systems.
(b) Operating instructions for the equipment and systems (including fire isolation aspects).
(c) Maintenance instructions for the installed arrangements.

■ *Section 2*
Construction and installation

2.1 Materials

2.1.1 The selection of materials in piping systems for provision refrigeration systems is to recognise the following details:

(a) Fluids, pressures and temperatures.
(b) Location.
(c) Compatibility of materials.
(d) Fluid flow rates and static conditions.
(e) Minimising corrosion and erosion through life of system.
(f) Flammability and toxicity.

2.1.2 Pipes, valves and fittings are in general to be made of steel, ductile cast iron, copper, copper alloy, or other approved ductile material suitable for the intended purpose. The use of plastics materials is also acceptable, subject to the restrictions in *Vol 2, Pt 7, Ch 1 Piping Design Requirements*.

2.1.3 Where applicable, the materials are to comply with the requirements of *Vol 2, Pt 7, Ch 1 Piping Design Requirements*.

2.2 Equipment - Selection and installation

2.2.1 Pressure vessels in provision refrigeration systems are to be in accordance with *Vol 2, Pt 8, Ch 2 Other Pressure Vessels* or a recognised Code.

2.2.2 Valves, flexible hose lengths, expansion pieces and pumps are to comply with the relevant requirements of *Vol 2, Pt 7, Ch 1, 12 Valves*.

2.2.3 Pipes in piping systems are to be permanent pipes made with approved pipe connections to enable ready removal of valves, pumps, fittings and equipment. The pipes are to be efficiently secured in position to prevent chafing or lateral movement.

2.2.4 Suitable means for expansion is to be made, where necessary, in each range of pipes.

2.2.5 Suitable protection is to be provided for all pipes and equipment situated where they are liable to mechanical damage.

2.2.6 All moving parts are to be provided with guards to minimise danger to personnel.

2.2.7 Low temperature pipes in refrigeration systems are to be provided with suitable insulation.

2.3 Valves and relief devices

2.3.1 Valves are to be fitted in places where they are at all times readily accessible.

2.3.2 Relief valves are to be adjusted and bursting discs so selected that they relieve at a pressure not greater than the design pressure of the system. When satisfactorily adjusted, relief valves are to be protected against tampering or interference by wire with a lead seal or similar arrangement.

2.4 Refrigerant systems

2.4.1 Refrigeration plants are to be provided and designed to be capable of extracting the defined heat load duty when operating in accordance with the conditions stated in the System Design Description required by *Vol 3, Pt 2, Ch 3, 1.2 Documentation required for design review 1.2.2*.

2.4.2 The compartments containing the refrigeration plants are to be provided with refrigerant gas detectors with an alarm.

2.4.3 The design of refrigeration systems is to be such that it permits maintenance and repair without unavoidable loss of refrigerant to the atmosphere. To minimise refrigerant release to the atmosphere, refrigerant recovery units are to be provided for evacuation of a system prior to maintenance.

2.4.4 Refrigeration systems are to be provided with relief devices, but it is important to avoid circumstances that would bring about an inadvertent discharge of refrigerant to the atmosphere. The system is to be so designed that pressure due to fire conditions will be safely relieved.

2.4.5 A pressure relief valve and/or bursting disc is to be fitted between each positive displacement compressor and its gas delivery stop valve, the discharge being led to the suction side of the compressor. The flow capacity of the valve or disc is to exceed the full load compressor capacity on the particular refrigerant at the maximum potential suction pressure. For these internal relief valves, servo-operated valves will be accepted. Where the motive power for the compressor does not exceed 10 kW, the pressure relief valve and/or bursting disc may be omitted.

2.4.6 Each pressure vessel which may contain liquid refrigerant and which is capable of being isolated by means of a stop or automatic control or check valves is to be protected by two pressure relief valves or two bursting discs, or one of each, controlled by a changeover device. Pressure vessels that are connected by pipework without valves, so that they cannot be isolated from each other, may be regarded as a single pressure vessel for this purpose, provided that the interconnecting pipework does not prevent effective venting of any pressure vessel.

2.4.7 Omission of one of the specified relief devices and changeover device, as required by *Vol 3, Pt 2, Ch 3, 2.4 Refrigerant systems 2.4.6*, will be accepted where:

(a) Vessels are of less than 300 litres internal gross volume;

or

(a) Vessels discharge into the low pressure side by means of a relief valve.

2.4.8 Sections of systems and components that could become full of liquid between closed valves are to be provided with pressure relief devices relieving to a suitable point in the refrigerant circuit.

2.4.9 Where hermetically sealed compressor units or semi-hermetic compressors with the electric motor cooled by the circulating refrigerant are installed, the following arrangements are to be made:

(a) Each refrigeration system containing hermetically sealed compressor units or semi-hermetic compressors is to be independent of other refrigeration systems.
(b) All hermetic motor-compressors are to be fitted with a thermal cut-out device that protects the motor against overheating.
(c) Each refrigerant circuit is to be designed such that debris or contaminants from a motor failure, typically burn out of insulation, is contained and not distributed around the system.
(d) The pressure envelope of any hermetic or semi-hermetic compressor exposed to the refrigerant pressure is to be designed and constructed in accordance with the requirements of *Vol 2, Pt 8, Ch 2 Other Pressure Vessels* and *Vol 2, Pt 1, Ch 4 Requirements for Fusion Welding of Pressure Vessels and Piping* as applicable. Plans are to be submitted for consideration as required by *Vol 2, Pt 8, Ch 2, 1.6 Plans*.

2.4.10 Sea-water systems for refrigeration condensers are to be capable of being supplied from not less than two independent sources. If specified, these sources are to be located in separate compartments and zones such that the loss of one zone or compartment will not result in the loss of all sea-water supply sources.

2.4.11 The capacity of each source of seawater required by *Vol 3, Pt 2, Ch 3, 2.4 Refrigerant systems 2.4.10* is to be sufficient for the conditions stated in the System Design Description with any one source out of action.

2.5 Air coolers and cooling grids

2.5.1 Refrigerated spaces may be cooled by air coolers or cooling grids on the deckhead, bulkheads, and sides. In order to minimise the dehydration of the stores and the frosting of the air coolers or cooling grids, the installation is to be designed to maintain the required temperatures as defined in the System Design Description with a minimum of difference between the refrigerant and space temperatures.

2.5.2 The refrigeration capacity of the air cooler arrangement is to be such that the provisions room temperature conditions defined in the System Design Description can be maintained under normal operating conditions. The capacities of the fans are also to be such that they can maintain the required air flow rates and uniform air temperature throughout the refrigerated spaces, when part or fully loaded with stores.

2.5.3 Air cooler fan motors are to be suitably enclosed to withstand the effects of moisture.

2.5.4 Means are to be provided for effectively defrosting air coolers. Air coolers are to be provided with trays of suitable depth arranged to collect all condensate. The trays are to be provided with drains at their lowest points to enable the condensate to be drained away when the refrigerated spaces are in service. Provision is to be made for the prevention of freezing of the condensate.

2.5.5 Air coolers are to be located such that when the refrigerated spaces are loaded with stores, adequate space is provided for the inspection, servicing and renewal of controls, valves, fans and fan motors.

2.5.6 Steel air cooler circuits and cooling grids are to be suitably protected against external corrosion.

2.6 Refrigeration units

2.6.1 A refrigerating unit is considered to comprise a compressor, its driving motor and one condenser. Where a secondary refrigerant, such as brine, is employed, the unit is also to include an evaporator (secondary refrigerant cooler) and a secondary refrigerant pump.

2.6.2 Two or more compressors driven by a single motor, or having only one condenser or evaporator/secondary refrigerant cooler, are to be regarded as one unit.

2.6.3 The refrigerating units of a classed provision stores installation are to be completely independent of any refrigerating machinery associated with air conditioning plant, unless full details of any proposal have been submitted and approved.

2.7 Design pressures

2.7.1 The design pressure of the system will be regarded as equal to its maximum working pressure.

2.7.2 The maximum working pressure is the maximum permissible pressure within the system (or part system) in operation or at rest. No relief valve is to be set to a pressure higher than the maximum working pressure.

2.7.3 The design pressure of the low pressure side of the system is to be the saturated vapour pressure of the refrigerant at plus 46°C. Due regard is to be taken of defrosting arrangements which may cause a higher pressure to be imposed on the low pressure system.

2.7.4 The minimum design pressure of the high pressure side of the system (P_{dh}), is to be 1,11 × P_b, where P_b is an allowance for the compressor high pressure cut-out. P_b is to be at least equal to 1,11 × P_a, where P_a is the condenser working pressure, when operating in tropical zones and equates to the saturation pressure at 46°C.

2.7.5 Design pressures (bar g) applicable to refrigerants are to be not less than the values given in *Table 3.2.1 Pressure limits* when condensers are sea-water cooled. The design pressure for other refrigerants is to be agreed with LR.

Table 3.2.1 Pressure limits

Refrigerant	Pressure (bar g)	
	High	Low
R-22	20,6	16,7
R-290	18,1	14,7
R-600a	6,4	5,2
R-134a	13,4	10,9
R-407C	23,5	19,0
R-410A	34,5	28,0
R-507A	25,3	20,5
R-404A	24,8	20,1

Note In view of increasing world-wide restrictive legislation and phasing out of the refrigerant R-22, it is recommended that this refrigerant should not be used in any new installation.

2.8 Room insulation

2.8.1 Where applicable, having regard to their location and environmental conditions, insulation materials are to be:

- suitably resistant to fire;
- suitably resistant to the spreading of flame;
- adequately protected against penetration of water vapour; and
- adequately protected against mechanical damage.

2.8.2 The potential for smoke generation and its toxicity is to be in accordance with *Regulation 6 - Smoke generation potential and toxicity*.

2.8.3 Where the *in situ* foam type of insulation is proposed, full details of the process are to be submitted for approval.

Section 3
Refrigerating machinery and refrigerant storage compartment arrangements

3.1 General

3.1.1 Refrigerating machinery is to be located in a well ventilated compartment. In general, the arrangements are to be such that all components of the refrigerating machinery can be readily opened up for inspection or replacement. Space is to be provided for the withdrawal and renewal of the tubes in `shell-and-tube' type evaporators (secondary refrigerant coolers) and condensers. Proposals for alternative arrangements are to be submitted to LR for consideration.

3.1.2 Refrigerating machinery using toxic and/or flammable refrigerants is to be located outside the main machinery space in a separate gastight compartment.

3.1.3 Where the refrigerating machinery is located in a separate gastight compartment, outside the main machinery space, this compartment is to be equipped with effective mechanical ventilation to provide 30 air changes per hour based upon the total volume of the space. The mechanical ventilation is to have two main controls, one of which is to be operable from a place outside the compartment.

3.1.4 Openings for pipes, electrical cables and other fittings in the bulkheads and deck are to be fitted with gastight seals.

3.2 Gas storage compartments

3.2.1 Portable steel cylinders containing reserve supplies of refrigerant are to be stored in the refrigerating machinery space or a well ventilated compartment reserved solely for this purpose.

3.2.2 The storage compartment is to be provided with a mechanical ventilation system providing 10 air changes per hour.

3.2.3 The storage compartment is to be provided with a suitable vapour detection system.

3.2.4 The storage compartment is to be provided with suitable water drainage arrangements not connected with the main machinery spaces.

3.2.5 Steel storage cylinders are to be of an approved type and are to be filled to a level suitable for an ambient temperature of plus 46°C.

3.2.6 The storage compartment is to be provided with racks to facilitate secure stowage of the cylinders.

3.3 Pressure testing at manufacturers' works

3.3.1 Components intended for use with a primary refrigerant are to be subject to strength and leak pressure tests as detailed in *Table 3.3.1 Test pressure*.

3.3.2 Component strength pressure tests are to be hydraulic or, where suitable safety measures are taken, may be pneumatic. The latter is to be carried out with a suitable dry inert gas.

3.3.3 Component leakage pressure tests are to be carried out only after completion of satisfactory strength pressure tests. Pneumatic pressure is to be applied using a suitable dry inert gas.

3.3.4 Components for use with a secondary refrigerant or cooling water are to be hydraulically tested to 1,5 times the design pressure, which in no case is to be less than 3,5 bar g.

3.4 Pressure test after installation on board ship

3.4.1 For primary refrigerant piping welded in place, strength pressure tests of the welds are to be carried out at a test pressure of 1,5p. This will normally take the form of a pneumatic test since hydraulic testing media such as water are not acceptable due to their incompatibility with the primary refrigerants and the difficulty of removing all traces from a completed system.

3.4.2 Pneumatic pressure tests are to be carried out using a suitable inert gas. All pneumatic tests are potentially dangerous and due precautions are to be observed.

3.4.3 Where pneumatic tests are prohibited by relevant authorities, the tests required by *Vol 3, Pt 2, Ch 3, 3.3 Pressure testing at manufacturers' works 3.3.1* and *Vol 3, Pt 2, Ch 3, 3.3 Pressure testing at manufacturers' works 3.3.2* may be omitted provided non-destructive examination has been carried out by an approved operator to the satisfaction of LR and in accordance with the requirements of *Vol 2, Pt 1, Ch 4, 6 Non-Destructive Examination*.

3.4.4 After completion of the test required by *Vol 3, Pt 2, Ch 3, 3.3 Pressure testing at manufacturers' works 3.3.1*, *Vol 3, Pt 2, Ch 3, 3.3 Pressure testing at manufacturers' works 3.3.2* or *Vol 3, Pt 2, Ch 3, 3.3 Pressure testing at manufacturers' works 3.3.3*, a leak pressure test is to be carried out using a suitable inert gas at a pressure equal to the design pressure, in the presence of the Surveyor.

3.4.5 Secondary refrigerant piping welded in place is to be hydraulically tested to 1,5 times the design pressure, which in no case is to be less than 3,5 bar g.

Table 3.3.1 Test pressure

Component	Test pressure, (bar g)	
	Strength test	Leakage test
1. Pressure vessels	*See Vol 2, Pt 8, Ch 2 Other Pressure Vessels*	1,0p
2. Compressor cylinders/ crankcase/casing	1,5p	1,0p
3. Valves & fittings	2,0p	1,0p
4. Pressure piping, fabricated headers, air coolers, etc.	1,5p	1,0p
Note p is the design pressure as defined in *Vol 3, Pt 2, Ch 3, 2.7 Design pressures*.		

■ *Section 4*
Refrigerant detection systems

4.1 General

4.1.1 A fixed refrigerant detection system is to be provided in the refrigerating machinery compartment or space and ventilation outlet ducts when the ventilation system is shared with other compartments.

4.1.2 The alarm system is to comply with the requirements of *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems* and, as a minimum requirement, the system is to activate at a low-level concentration to give warning of refrigerant leaks, and a highlevel concentration corresponding to the refrigerant's safe occupational level.

4.1.3 Detection equipment is to be so designed that it may be readily tested and calibrated, and failure of the equipment is to initiate an alarm.

4.1.4 The location of the detectors is to be determined relative to the layouts of the individual compartments and machinery spaces and is to be indicated on the plan submission.

4.1.5 Audible and visual alarms are to be activated, located both inside and outside the affected space. The alarms are to be readily identifiable and be visible and audible in all locations within the space housing the refrigeration equipment.

■ Section 5
Control and monitoring and electrical power arrangements

5.1 General

5.1.1 The control engineering arrangements are to comply with *Vol 2, Pt 9, Ch 1 General Requirements for the Design and Construction of Electrotechnical Systems* & *Vol 2, Pt 9, Ch 7 Control, Alerts and Safety Systems* as applicable.

5.1.2 The equipment used in provision refrigeration systems is to be provided with local control and monitoring arrangements.

5.1.3 Where isolation of equipment or systems can be carried out, means of indicating the status of isolation is to be provided at positions where the equipment and system can be operated and monitored.

5.1.4 Instrumentation to indicate the operational status of running and any standby equipment is to be provided locally and at any control station.

5.1.5 All cooling and secondary refrigerant pumps are to be provided with an indication of discharge pressure and a low discharge pressure alarm at each control station.

5.1.6 The power to all independently driven ventilation fans is to be capable of being stopped from position(s) outside the fire boundary which will always be readily accessible in the event of fire occurring in any space, as well as from the local control panel.

5.1.7 Electrical engineering arrangements are to comply with *Vol 2, Pt 9 Electrotechnical Systems*.

5.1.8 Refrigeration compressors are to be provided with the following instrumentation and automatic shutdowns:

(a) Indication of suction pressure (saturated temperature), including intermediate stage when applicable.
(b) Indication of discharge pressure (saturated temperature), including intermediate stage when applicable.
(c) Indication of lubricating oil pressure.
(d) Indication of cumulative running hours.
(e) Automatic shutdown in the event of low lubricating oil pressure.
(f) Automatic shutdown in the event of high discharge pressure which is to operate at a pressure in excess of normal operating pressure but not greater than 0,9 of the maximum working pressure.
(g) Automatic shutdown in the event of a low suction pressure.

5.1.9 For refrigeration compressors greater than 25 kW, the following instrumentation, additional to that required by *Vol 3, Pt 2, Ch 3, 5.1 General 5.1.8*, is to be provided:

(a) Indication of lubricating oil temperature.
(b) Indication of cooling water outlet temperature.
(c) Indication of cumulative running hours (reciprocating compressors).
(d) Indication of suction and discharge temperatures.

5.1.10 Alarms are to be initiated in the event of the following fault conditions with refrigeration compressors:

(a) High discharge pressure.
(b) Low suction pressure.
(c) Low oil pressure.
(d) High discharge temperature.
(e) High oil temperature.
(f) Motor shutdown.

5.1.11 Refrigeration plants are to be provided with the following alarms as applicable:

(a) Failure of condenser cooling water pumps.
(b) High condenser cooling water outlet temperature.
(c) Failure of air cooler fans.
(d) High and low refrigerated air delivery temperatures.
(e) High secondary refrigerant temperatures.
(f) Failure of secondary refrigerant pump.
(g) Low level in secondary refrigerant header tank.

■ Section 6
Personnel safety equipment and systems

6.1 Personnel safety equipment

6.1.1 Access doors to the refrigerated spaces are to open outwards and an external locking arrangement is to be provided to prevent unauthorised access.

6.1.2 Access ways to the refrigerated spaces are to be designed to facilitate escape in emergencies, and the removal of stretcher-borne personnel.

6.1.3 Access ways and refrigerated compartments are to be provided with an independent lighting system in accordance with the requirements of *Vol 2, Pt 9, Ch 6, 4.3 Lighting circuits 4.3.2* and *Vol 2, Pt 9, Ch 3, 4.7 Lighting circuits 4.7.1*, with the means of locking the switches in the `on' position.

6.1.4 Arrangements are to be such that means of both opening the room door(s) and sounding the alarm required by *Vol 3, Pt 2, Ch 3, 6.2 Personnel warning systems 6.2.2* from inside refrigerated spaces are provided.

6.2 Personnel warning systems

6.2.1 A system to monitor the well-being of crew members entering refrigerated spaces is to be provided.

6.2.2 The system is to be such that at a predetermined time, after initiation, the crew member(s) receives warning that the system is to alarm and must indicate their well-being by accepting the warning.

6.2.3 The system is to be designed and arranged such that only an authorised person has access for enabling and disabling it and setting the appropriate intervals, and such that it cannot be operated in an unauthorised manner.

6.2.4 It is to be possible to acknowledge the warning by means of illuminated switches situated near the access doors or hatches of each refrigerated space or chambers within the space.

6.2.5 In the event that the crew member(s) fails to respond and accept the warning within an agreed specified time, the system is immediately to initiate an alarm on the bridge and at the main control station, or subsidiary control stations as appropriate. Manual initiation of the alarm system from the refrigerated spaces is to be possible at any time.

6.2.6 The system is to comply with the relevant requirements of *Vol 2, Pt 9, Ch 1 General Requirements for the Design and Construction of Electrotechnical Systems*.

■ Section 7
Testing and trials

7.1 Testing

7.1.1 The requirements of the Rules relating to testing of pressure vessels, piping and related fittings including hydraulic testing are applicable. *See Vol 2, Pt 8, Ch 2, 10 Hydraulic tests*and *Vol 2, Pt 7, Ch 1, 16 Testing*.

7.1.2 On completion, tanks and reservoirs for service and storage of system fluids are to be tested by a head of water equal to the maximum to which the tanks may be subjected, but not less than 2,5 m above the crown of the tank.

7.1.3 After installation on board, piping systems together with associated fittings that are under internal pressure, are to be subjected to a running test at the intended maximum working pressure.

7.1.4 Testing is to cover the following items:

(a) Verification of control, alarm, safety systems.
(b) Tests simulating failure of refrigeration equipment to verify correct functioning of alarms and systems in service.
(c) Verification of accuracy, calibration and functioning of temperature control for refrigeration systems.

7.2 Type testing

7.2.1 Evidence that the required performance of refrigeration systems, pump and fan equipment is capable of being maintained under ambient and inclination operating conditions defined in *Vol 2, Pt 1, Ch 3, 4.4 Ambient reference conditions* is to be provided by the manufacturer.

7.3 Trials

7.3.1 Trials are to be carried out to demonstrate that the capability of the provision refrigeration systems meets the System Design Description. The trials are as far as practicable to be representative of the actual conditions to be encountered in service.

■ *Section 1* **Scope**

1.1 Application

1.1.1 The Chapters in this Part of the Rules define the requirements for the design and service life of safety equipment and arrangements. The Chapters are provided for the purpose of assessing that the levels of safety (of crew and embarked personnel) and pollution prevention on board a naval ship are to a standard which is acceptable to the Naval Administration and Lloyd's Register (hereinafter referred to as LR). The Rules provide a standard that can be considered to be as far as reasonably practicable in accord with the applicable IMO International Conventions but take due cognisance of military application. They also provide a methodology for assessing the suitability of designs that deviate from generally accepted practice.

1.1.2 In general, a Class Notation contained in this Part of the Rules will only be assigned where the vessel has been assigned an **LMC** notation, *see Vol 1, Pt 1, Ch 2 Classification Regulations*. However where a Certificate of Compliance is sough,t it may be demonstrated that an equivalent provision of equipment and arrangements is provided on board the vessel. In addition, the equipment and arrangements are also to be in compliance with the applicable Sections of *Vol 1 Ship Structures* and *Vol 2 Machinery and Engineering Systems* of these Rules. Other acceptable standards such as Naval Defence Standards or *ANEP-77 NATO Naval Ship Code* (NSC) may be used subject to satisfactory review by LR.

1.1.3 These Rules are applicable only to ships carrying crew and embarked personnel. The carriage of passengers is considered novel for most naval ships and will generally only be undertaken during emergency situations or where specially agreed by the Owner. The carriage of passengers is therefore outside the scope of these Rules. Special consideration will be given to arrangements where passengers are carried.

1.1.4 The interpretation of the Rules is the sole responsibility, and at the sole discretion, of LR.

1.1.5 Where *SOLAS - International Convention for the Safety of Life at Sea* requirements have been identified as a route to satisfying goals associated with objectives, these are for guidance purposes. Where there is no specific *SOLAS - International Convention for the Safety of Life at Sea* guidance provided in the Rules, the designer can propose solutions to LR that embrace the recognised practices that are consistent with the overall *SOLAS - International Convention for the Safety of Life at Sea* philosophy.

1.2 Background

1.2.1 These Rules provide a framework and methodology for demonstrating that levels of safety and pollution prevention are to a standard acceptable to the Naval Administration and LR. The application of these Rules is not to compromise the levels of safety afforded to naval ships through the application of current regulatory regimes and military practices. The Rules recognise military design, construction, installation, testing, trials and through life operation and take due account of the military function of naval ships. The Rules provide a series of optional class notations that can be assigned to designs complying with relevant Parts of the Rules.

1.2.2 This Part of the Rules has been developed from the relevant requirements of:

- *SOLAS - International Convention for the Safety of Life at Sea*; and
- *SOLAS - International Convention for the Safety of Life at Sea*; and

- *ANEP-77 NATO Naval Ship Code* (NSC),

taking due consideration of military philosophy.

1.2.3 Military philosophy addresses ship survivability and system degradation that are two key areas that commonly affect the application of merchant ship statutory requirements and these have been recognised in the Chapters applicable to different Class notations.

1.2.4 Modern naval ships are commonly required to have multi-purpose roles and extensive operational capabilities and it is necessary to ensure that the equipment and arrangements on board do not compromise the roles within which the ship may be required to operate.

1.2.5 The assessment of the accceptability of equipment and arrangements required by these Rules is to ensure that a single failure of equipment will not render the system inoperable. Where this cannot be achieved, there is to be sufficient engineering evidence that the likelihood of failure occurring is extremely remote.

1.2.6 Levels of manning, personnel training and qualifications are not within the scope of these Rules; however, these will be given consideration when an alternative design approval is sought.

1.3 Scope of application

1.3.1 For the purposes of demonstrating compliance with these Rules, two alternatives are available:

(a) **Certificate of Compliance**, which provides evidence that the arrangements on board meet the requirements in the relevant Section of the Rules. This will be confirmed by appropriate design appraisal followed by inspection and testing at survey. Designs other than those prescribed by the Rules will be recorded for information purposes by way of an addition to the certificate as an Annex. Where a defect, blemish or anomaly is noted at survey, and is not considered to require remedial attention at that time, an Annex will be added to the certificate for information purposes.

(b) **Class Notation**, which indicates that the arrangements on board meet the requirements in the relevant Sections of the Rules and that a periodic survey regime of the equipment and systems has been established for the lifetime of the ship. When at any survey it is found that any damage, defect or breakdown is of such a nature that it does not require immediate permanent repair, but is sufficiently serious to require rectification by a prescribed date in order to maintain class, a suitable Condition of Class is imposed. The condition of class will be assigned with a date by which the repair is to be completed. Deviations from design standards will be recorded for information purposes as an Annex in the classification records. Likewise, where a defect, blemish or anomaly is noted at survey, and is not considered to require remedial attention at that time, an Annex will be included in the classification records for information purposes.

1.3.2 These Rules are not intended to apply to ships under construction or upkeep where additional personnel and equipment may be present on board the ship. In general the Rules are only intended to apply where the ship is under naval command.

1.4 Topics within this Part of the Rules

1.4.1 **EER** (Escape, emergency access, evacuation and rescue). This notation will be assigned to naval ships which demonstrate that the arrangements are in accordance with the requirements of these Rules or are to a standard which meets the Objectives specified in these Rules. For a ship to be eligible for **EER** notation, it is to be demonstrated that it is fully compliant with the requirements of *Vol 3, Pt 3, Ch 2 Fire Protection*, *Vol 3, Pt 3, Ch 3 Escape and Emergency Access* and *Vol 3, Pt 3, Ch 4 Life-Saving and Evacuation Arrangements* of this Part of the Rules, i.e. **FIRE**, **ESC** and **LSAE** notations are to be capable of being assigned to the vessel. System integration is to be in accordance with *Vol 3, Pt 3, Ch 1, 4 Integration for EER notation* of this Chapter.

1.4.2 **FIRE** – Fire Protection. This notation will be assigned to naval ships which demonstrate that the provision of fire protection equipment and arrangements on board a vessel comply with the requirements of *Vol 3, Pt 3, Ch 2 Fire Protection* of this Part of the Rules.

1.4.3 **ESC** – Escape and Emergency Access. This notation will be assigned to naval ships which demonstrate that the escape arrangements and emergency access on board comply with the requirements of *Vol 3, Pt 3, Ch 3 Escape and Emergency Access* of this Part of the Rules. Where the requirements of the NSC are to be applied for an **ESC★★** notation, the **LSAE★★** notation must also be applied.

1.4.4 **LSAE** – Life Saving and Evacuation Arrangements. This notation will be assigned to naval ships which demonstrate that the life saving, evacuation and rescue arrangements on board comply with the requirements of *Vol 3, Pt 3, Ch 4 Life-Saving and Evacuation Arrangements* of this Part of the Rules. Where the requirements of the NSC are to be applied for an **LSAE★★** notation, the **ESC★★** notation must also be applied.

1.4.5 **SNC** – Safety of Navigation and Communication. This notation will be assigned to naval ships which demonstrate that the navigation and communication equipment on board comply with the requirements of *Vol 3, Pt 3, Ch 5 Safety of Navigation and Communication* of this Part of the Rules.

1.4.6 **POL** – Pollution Prevention. This notation will be assigned to naval ships which demonstrate that the pollution prevention measures on board comply with the requirements of *Vol 3, Pt 3, Ch 6 Pollution Prevention* of this Part of the Rules.

1.4.7 **Star Endorsements**(★). All Class Notations that are available in this Part of the Rules will be eligible for a 'Star' endorsement where the arrangements on board are in accordance with stated National Administration requirements. This does not necessarily denote automatic endorsement by the National Administration.

1.4.8 **Double Star Endorsements** (★★). All Class Notations that are available in *Vol 3, Pt 3, Ch 2 Fire Protection*, *Vol 3, Pt 3, Ch 3 Escape and Emergency Access* and *Vol 3, Pt 3, Ch 4 Life-Saving and Evacuation Arrangements* of this Part of the Rules will be eligible for a 'Double Star' endorsement where the arrangements on board are in accordance with the requirements of *ANEP-77 NATO Naval Ship Code* (NSC) plus any Naval Administration requirements as specified.

■ *Section 2*
General Information

2.1 Responsibilities

2.1.1 **Lloyd's Register** (Classification Society) is responsible for confirming and accepting that equipment and arrangements required by the applicable Rules and requirements associated with a particular class notation are satisfied. *See Vol 1, Pt 1, Ch 2, 1.3 Interpretation of the Rules 1.3.1* regarding interpretation of the Rules.

2.1.2 The **National Administration** is responsible for confirming that the equipment and arrangements are acceptable to them for recognition of the requirements associated with a particular class notation with a star (★) endorsement, *see Vol 3, Pt 3, Ch 1, 1.4 Topics within this Part of the Rules 1.4.7*.

2.1.3 The **Naval Administration** is responsible for confirming that the equipment and arrangements are acceptable to them for recognition of the requirements associated with a particular class notation with a Double Star (★★) endorsement, *see Vol 3, Pt 3, Ch 1, 1.4 Topics within this Part of the Rules 1.4.8*.

2.1.4 The **designer** is responsible for co-ordination of all matters relating to demonstrating compliance with the Rules and any requirements of the Naval Administration as specified by the Owner.

2.1.5 The **Owner** has ultimate responsibility for ensuring a safety standard acceptable to the Naval Administration is being applied, *see also Vol 1, Pt 1, Ch 2, 1.4 Owner's responsibilities*.

2.2 Appraisal and review

2.2.1 Prior to the formal appraisal process being commenced a System Operational Concept is to be submitted and agreed with LR, *see Vol 3, Pt 3, Ch 1, 2.3 Documentation required for design review 2.3.2*.

2.2.2 A design disclosure is to be submitted to LR for appraisal as required by the applicable parts of the Rules.

2.2.3 All systems are to be constructed and assembled from equipment suitable for its intended purpose and acceptable to the National Administration and/or the Naval Administration where a 'Star' or 'Double Star' endorsement is required. Such equipment will typically have a relevant Type Approval Certificate or an EC Marine Equipment Directive Certificate issued by LR or an organisation acceptable to LR. Equipment with other certification may be acceptable as an alternative subject to a satisfactory review by LR. Details will be noted as an Annex in the applicable certification or class documentation, *see Vol 3, Pt 3, Ch 1, 1.3 Scope of application 1.3.1*.

2.3 Documentation required for design review

2.3.1 The Concept of Operations including the ship's civil and military operational profile specifying the functionality and capability in defined operating and foreseeable failure conditions of the ship is to be submitted. This is to be provided by the Owner.

2.3.2 A System Operational Concept detailing the capability and functionality of the system under consideration detailing defined civil and military operating and emergency conditions is to be submitted. The System Operational Concept is to include but is not limited to:

(a) Required Certificates of Compliance or Class Notations.
(b) Description of the ship's operational capabilities, to include any defined military survivability requirements.
(c) Details of the intended mode of operation of the equipment/system to include environmental conditions.
(d) Manning levels and operator competencies/authorisations required.
(e) Indication of whether or not alternative design assessment is being sought if the proposed design deviates from the specified guidance identified in these Rules.

2.3.3 In addition to the submission of an acceptable System Operational Concept, a more detailed Design Disclosure is required for submission to and acceptance by LR. The Design Disclosure is to include, but is not limited to:

(a) A statement of all design standards used in the design, manufacture, installation and testing of safety and pollution prevention systems.
(b) A proposed list of all surveyable items together with any additional recommendations from equipment/component manufacturers. Evidence is also to be provided that all surveyable items of equipment have approval certificates.
(c) Evidence of compliance with the Objectives and Goals defined in the Chapter of the Rules applicable to that system. This may be in the form of compliance with any specified guidance / technical references, Concessions, Alternative Design Justification Reports or an acceptable combination of all three, *see Vol 3, Pt 3, Ch 1, 6 Route to conformance*.
(d) Details of the hazard identification process and Class related hazards are to be submitted. A hazard identification system is to be in place at the design stage whereby all hazards identified are recorded. If application of these Rules has been identified as a hazard avoidance/mitigation measure then details are to be submitted.
(e) Descriptions of designated places of safety and safe havens etc. as required by the relevant Chapters of the Rules.
(f) Details of the proposed test procedures required to demonstrate functionality at the time of commissioning for all systems covered by these Rules.

The details of the Design Disclosure are subject to review and acceptance by LR. A letter of acceptance will be issued by LR after satisfactory review of the Design Disclosure.

2.3.4 Where a Naval Administration has approved equipment, systems and arrangements which are usually subject to these Rules for Classification purposes, full details are to be submitted to LR for information. Details are to include information on the equipment/arrangements, certification and test reports.

2.4 Inspection and survey

2.4.1 The requirements for inspection and survey are such that it is to be demonstrated to LR that the arrangements on board the ship are in accordance with the description within those detailed in the Design Disclosure.

2.4.2 Where a Class Notation is requested, a survey regime is to be established to ensure that the arrangements on board are maintained to an acceptable standard as long as the vessel is to be assigned a particular Class Notation. All surveyable items as accepted in the Design Disclosure are to be included in the survey regime.

■ *Section 3* **Definitions**

3.1 Safety equipment and arrangements

3.1.1 **Escape**. Movement of personnel to a designated place of safety on board. (This may be co-ordinated movement or the action of individuals. Since this is mainly concerned with the flow of personnel through the ship it may also be taken to include normal access).

3.1.2 **Evacuation**. Movement of all personnel to a survival craft in case of an emergency.

3.1.3 **Rescue**. Process by which personnel are taken to an ultimate point of safety. (This definition does not include the ability to conduct Search and Rescue but covers the ability to locate and rescue personnel in an emergency). (Search is covered by the **SNC** notation, *see Vol 3, Pt 3, Ch 5 Safety of Navigation and Communication*).

3.1.4 **Ultimate point(s) of safety** is/are to be declared in the Design Disclosure, and can, amongst other things, be another vessel, aircraft or dry land.

3.1.5 **Designated place(s) of safety** is/are to be declared in the Design Disclosure. These are to be places on board the vessel which may be reasonably expected to be used as platforms for evacuation following escape.

3.1.6 **Emergency access** arrangements allowing for movement of personnel within the ship for the purposes of damage control and fire-fighting.

3.1.7 **Alternative design and arrangements** mean safety and pollution prevention measures which deviate from any prescriptive requirement(s) of these Rules, but are acceptable to LR to satisfy the objective(s) and the functional requirements of the relevant Chapter. The term includes a wide range of measures, including alternative shipboard structures and systems based on novel or unique designs, as well as traditional shipboard structures and systems that are installed in alternative arrangements or configurations. Depending on the nature and extent of the deviation, it will be accepted in accordance with *Vol 3, Pt 3, Ch 1, 6.2 Alternative arrangements and calculation methods*.

3.1.8 **Design hazard** means an engineering description of a hazard which is identified at the design stage.

3.1.9 **Design scenario** means a set of conditions and incidents which may reasonably be expected to occur during the life of a system. These conditions and incidences are to be used in identifying the design hazards.

3.1.10 **Functional requirements** explain, in general terms, what function the ship and shipboard systems/equipment must provide in order to meet the safety objectives of these Rules.

3.1.11 **Hazard identification** is the process whereby all hazards identified at the design stage are catalogued.

3.1.12 **Locating signals** are radio transmissions intended to facilitate the finding of a mobile unit in distress or the location of survivors. These signals include those transmitted by searching units, and those transmitted by the mobile unit in distress, by survival craft, by float-free EPIRBs (Emergency Position-Indicating Radio Beacons), by satellite EPIRBs and by search-and-rescue radar transponders to assist the researching units.

3.1.13 **Performance criteria** are measurable quantities stated in engineering terms to be used to judge the adequacy of trial designs.

3.1.14 Personnel:

(a) **Crew**. All personnel on board the ship for its operational role. This includes personnel for navigation and maintenance of the ship, its machinery and weapons/aircraft systems. Naval trainees on board for the purpose of training in naval operations identified in the previous sentence are also within the scope of the definition of crew.
(b) **Embarked personnel**. Additional personnel other than crew, embarked on the ship for a specific task or purpose or for military purposes. Such personnel may include additional specialised maintenance personnel for ship systems, technicians on trials during normal operation, aircraft crew, and military personnel on a mission which may be any naval related activity under naval command including trials, training, humanitarian aid and military activities.
(c) **Passengers** is every person other than the crew and embarked personnel.

3.1.15 **Safety margin** means adjustments made to allow for uncertainties in the methods and assumptions used to evaluate an alternative design, *see Vol 3, Pt 3, Ch 1, 3.1 Safety equipment and arrangements 3.1.7*, e.g. in the determination of performance criteria or in the engineering models used to assess the consequences of a hazard.

3.1.16 **Sensitivity analysis** means an analysis to determine the effect of changes in individual input parameters on the results of a given model or calculation method.

3.1.17 **Survival craft**. A survival craft is a craft capable of sustaining the lives of personnel in distress from the time of evacuating the ship. This may include supporting ships and aircraft.

3.1.18 **Gross tonnage (GT)** of a ship is to be determined for the purposes of these Rules, by the following formula:

$$GT = K_1 V$$

where

V = total volume of all enclosed spaces in the ship in cubic metres and includes gun turrets, radar domes, masts, etc.

K_1 = $0{,}2 + 0{,}02 \log_{10} V$.

3.1.19 **Fire zones** are those sections into which the hull, superstructure and deckhouses are divided by fire resistant divisions. Fire resistant divisions are those which are installed and/or protected for the purpose of restricting the spread of fire.

■ *Section 4* Integration for EER notation

4.1 General

4.1.1 The **EER** notation will be assigned to ships which demonstrate compliance with all the requirements for **FIRE**, **ESC** and **LSAE** notations.

4.1.2 In addition to the requirements of *Vol 3, Pt 3, Ch 1, 4.1 General 4.1.1* the systems and their arrangements are to be integrated in such a manner so as to support safe and effective task performance. The systems are to be integrated in accordance with the requirements of *Vol 3, Pt 3, Ch 1, 4.2 System integration*.

4.2 System integration

4.2.1 System integration is to be managed by a single designated party, and is to be carried out in accordance with a defined procedure, agreed between the designer and the Owner.

4.2.2 The procedure is to identify the roles, responsibilities and requirements of all parties involved.

4.2.3 Safety systems are to be designed, as far as is practicable, so that their integration with other systems will not degrade the performance of any other system.

4.2.4 Where the integration involves control and safety functions for Mobility or Ship Type systems, a robust system Risk Assessment in accordance with *Vol 2, Pt 1, Ch 3, 17 Risk Assessment (RA)* is to be used. The Risk Assessment is to demonstrate that the integrated system will not render the control and safety functions of Mobility or Ship Type systems inoperable as a result of single item failure or cause failure of Mobility or Ship Type systems.

■ *Section 5* Acceptance criteria

5.1 General

5.1.1 The acceptance criteria ensure conformity of safety and pollution prevention systems to the Provisions of Classification, *see Vol 2, Pt 1, Ch 1, 2 Engineering system classification provisions* of LR's Rules and Regulations and specified Standards or Codes.

5.1.2 The route to conformance detailed in *Vol 3, Pt 3, Ch 1, 6 Route to conformance* provides details on the process for demonstrating that equipment and systems are acceptable to LR.

5.1.3 The acceptance criteria of safety and pollution prevention systems extend over the full lifecycle of the systems.

5.2 Design

5.2.1 The design of safety and pollution prevention systems is to be in accordance with these Rules.

5.3 Construction

5.3.1 Safety and pollution prevention systems and their components are to be constructed in accordance with standards acceptable to LR and which satisfy the Rule requirements.

5.4 Installation/testing

5.4.1 Safety and pollution prevention systems are to be installed in accordance with plans appraised by LR and Rule requirements to the satisfaction of LR.

5.5 Trials

5.5.1 Safety and pollution prevention systems are to be tested in accordance with a procedure agreed between LR and the designer.

5.6 Through life operations

5.6.1 Safety and pollution prevention systems are to be maintained through life such that the applicable Rule objectives and Provisions of Classification can be ascertained and found in a condition that is acceptable to LR.

5.7 Modifications

5.7.1 Details of all modifications to safety and pollution prevention systems and equipment are to be appraised and found acceptable to LR.

■ *Section 6* Route to conformance

6.1 Route to conformance

6.1.1 The Route to conformance in *Vol 3, Pt 3, Ch 1, 6.1 Route to conformance 6.1.3* provides the process for demonstrating that systems and equipment satisfy the acceptance criteria of *Vol 3, Pt 3, Ch 1, 5 Acceptance criteria*.

6.1.2 Conformance with this Part of the Rules is recognised by LR through the assignment of an associated Class Notation or issuing of a Certificate of Compliance.

6.1.3 The route to conformance throughout the life cycle requires the following:

(a) **Design**. Plans are to be appraised by LR when required by the Rules and where a military distinction notation has been requested by the Owner.
(b) **Construction**. To be constructed under survey where required by the Rules.
(c) **Installation**. Systems are to be installed under survey in accordance with plans appraised by LR and with Rule Requirements.
(d) **Trials**. Systems are to be tested under normal working conditions.
(e) **In Service**. Systems will be subject to survey where required by the Rules or Regulations or where requested by Owners or Naval Administration.
(f) **Modification**. Details of any modifications are to be appraised and construction, installation and trials are to be carried out under survey when required by the Rules for a Class notation.
(g) **Decommissioning**. Details are to be submitted for information.

6.2 Alternative arrangements and calculation methods

6.2.1 In addition to cases where direct calculations are specifically required by the Rules, LR will consider alternative arrangements that have been derived by direct calculations in lieu of specific Rule requirements. All direct calculations are to be submitted for examination.

6.2.2 Where items are of a novel or unconventional design or manufacture, it is the responsibility of the designer to demonstrate their suitability and equivalence to the Rule requirements. *See Requirements for Machinery and Engineering Systems of Unconventional Design*, *Vol 2, Pt 1, Ch 2 Requirements for Machinery and Engineering Systems of Unconventional Design*.

6.2.3 Alternative arrangements or fittings that are considered to be equivalent to the Rule requirements will be accepted in accordance with *Vol 1, Pt 1, Ch 2, 3.2 Tailoring – Departures from the Rules and Rule additions*.

■ *Section 1* Scope

1.1 Philosophy

1.1.1 The purpose of this Chapter is to provide a methodology for confirming that the arrangements on board a naval ship prevent fire occurring and reduce the consequences of damage to the ship or personnel arising from fire.

1.1.2 The Objectives of this Chapter as defined in *Vol 3, Pt 3, Ch 2, 4.2 Fire protection objectives* are to be realised through the contents of these Rules that aim to prevent the occurrence of fire and ensure any fire will be detected, located, extinguished and contained in its space of origin.

1.1.3 In general, demonstration of satisfactory levels of fire protection will be achieved through compliance with the relevant requirements of these Rules and the documents referenced therein. Where fire protection arrangements deviate from the specified guidance/technical references of this Chapter, they are to be capable of satisfying the functional requirements and fire safety objectives and goals of this Chapter.

1.1.4 This Chapter of the Rules is to be read in conjunction with *Vol 3, Pt 3, Ch 1 General Requirements*.

1.2 Application

1.2.1 The requirements of this Chapter of the Rules are applicable where a Certificate of Compliance or a Class Notation for Fire Protection, **FIRE**, is requested.

1.2.2 The ‘Star endorsement’ (★) will be assigned to vessels where the arrangements on board are in accordance with stated National Administration requirements. This does not necessarily denote automatic endorsement by the National Administration.

1.2.3 The ‘Double Star endorsement’ (★★) will be assigned to vessels where the arrangements on board are in accordance with stated Naval Administration requirements and *ANEP-77 NATO Naval Ship Code* (NSC) – Chapter VI Fire Safety. This does not necessarily denote automatic endorsement by the Naval Administration.

Section 2
Classification requirements for fire protection systems

2.1 General requirements - SOLAS

2.1.1 The Fire Protection **FIRE** notation will be assigned to naval vessels which are shown to have levels of fire protection in accordance with *Vol 3, Pt 3, Ch 2, 3 Documentation required for design review* of these Rules.

2.1.2 It is a prerequisite of the **FIRE** notation that an **LMC** notation, or equivalent, has been assigned to the vessel, *see Vol 3, Pt 3, Ch 1, 1.1 Application 1.1.2*.

2.2 General requirements - NSC

2.2.1 The Fire Protection **FIRE★★** notation will be assigned to vessels which can demonstrate that the levels of fire protection are in accordance with Chapter VI of the NSC.

2.2.2 Where the **FIRE★★** notation is to be assigned, an **LMC** notation must have been assigned, *see Vol 3, Pt 3, Ch 1, 1.1 Application 1.1.2*.

Section 3
Documentation required for design review

3.1 System Operational Concept

3.1.1 The design intent of any fire protection system is to be submitted in the form of a System Operational Concept and is to include but not be limited to:

(a) The required class notation, **FIRE**, **FIRE★** or **FIRE★★**. If a military distinction (**MD**) notation is required this is also to be declared, *see Vol 1, Pt 1, Ch 2, 3.8 Military Distinction notations*.
(b) Details of the intended mode of operation of the fire protection systems/equipment to include environmental conditions together with a description of any fire scenarios and their development and application in the design.
(c) Manning levels, drills, exercises and operator competencies/authorisations required.
(d) Indication of whether or not alternative design assessment is being sought, if the proposed design deviates from the specified guidance identified in these Rules.

The System Operational Concept is to be agreed by the designer and Owner, *see also Vol 3, Pt 3, Ch 1, 2.3 Documentation required for design review 2.3.2*.

3.2 Design disclosure

3.2.1 In addition to submission of an acceptable System Operational Concept, a Design Disclosure is required for submission to and acceptance by Lloyd's Register (hereinafter referred to as 'LR'). The Design Disclosure is to include, but is not limited to:

(a) A statement of all design standards used in the design, manufacture, installation and testing of fire protection systems.
(b) A proposed list of all surveyable items together with any additional recommendations from equipment/component manufacturers. Evidence is also to be provided that all surveyable items of equipment have approval certificates.
(c) Details of the proposed survey and maintenance regime.
(d) Evidence of compliance with the Objectives and Goals defined in *Vol 3, Pt 3, Ch 2, 5 Fire prevention*. This may be in the form of compliance with specified guidance/technical references, Concessions, Alternative Design Justification Reports or an acceptable combination of all three. *See also Vol 3, Pt 3, Ch 1, 2.3 Documentation required for design review* and *Vol 3, Pt 3, Ch 6 Pollution Prevention*.
(e) Details of the Hazard Identification process and Class related hazards are to be submitted. A hazard identification system is to be in place at the design stage whereby all hazards identified are recorded. If application of these Rules has been identified as a hazard avoidance/mitigation measure, then details are to be submitted.
(f) Details of equipment configurations that are safe for operators and users.
(g) Details of the proposed test procedure required to demonstrate functionality at the time of commissioning.

(h) Details of system interaction, *see Vol 3, Pt 3, Ch 2, 10 System interaction*.

3.3 Plans

3.3.1 To support the Design Disclosure and for the purposes of assessing compliance with design requirements, for inspection installation and testing, guidance on the plans and details to be submitted for assessment and review are detailed in *Vol 3, Pt 3, Ch 2, 3.3 Plans 3.3.2* and *Vol 3, Pt 3, Ch 2, 3.3 Plans 3.3.4*.

3.3.2 For fire safety arrangements, the following plans and information:

(a) A statement of the method of structural fire protection adopted and prevention of fire spread.
(b) A general arrangement plan showing main fire zones, escape routes and the fire compartmentalisation bulkheads and decks within main fire zones, including the machinery spaces, magazine spaces, equipment spaces, vehicle and aircraft spaces, accommodation areas, galleys, paint stores, inflammable substance stores, navigating bridge, weapon/aircraft operating/ control rooms, store rooms, fuel tanks, fire-fighting control room and emergency generators. The plan should also include location of fire command and control stations. Where fire parties are utilised, the location of each control station in each fire zone is to be indicated.
(c) A plan showing the details of construction of the fire protection bulkheads and decks and the particulars of any surface laminates employed.
(d) Copies of certificates of any approval in respect of fire divisions, non-combustible materials and materials having low flame spread properties, etc. which are to be used but have not been approved by LR.
(e) A plan showing the construction and operation of fire doors.
(f) A ventilation plan showing ducts, any smoke extractor facilities and any dampers in them, and the position of controls for operation.
(g) A plan showing the location and arrangement of the emergency stop for flammable oil unit pumps and for closing the valves on pipes from flammable oil tanks.
(h) An arrangement plan of the fire alarms if applicable.

3.3.3 For fire-extinguishing arrangements, the following plans and information:

(a) A general arrangement plan showing the location of all the fire-fighting equipment including the fire extinguishing water system, the fixed fire-extinguishing systems in magazines, vehicle and aircraft spaces, on deck and in the machinery spaces; the disposition of the portable and non-portable extinguishers and the types used; and the position and details of the fire-fighters' outfits.
(b) A plan showing the layout and construction of the fire extinguishing water system, including all the designated fire pumps, isolating valves, pipe sizes and materials, the international shore connections and the cross-connections to any other systems.
(c) A plan showing details of each fixed fire-fighting system, including calculations for the quantities of the media used and the proposed rates of application.
(d) A plan showing any sprinkler and/or detection equipment locations, as applicable.
(e) Details of fire parties and availability of fire-fighters' outfits.

3.3.4 A fire control plan that is to be permanently exhibited for the guidance of the ship's crew, showing clearly for each deck the control stations, the various fire sections together with particulars of the fire detection and alarm systems, the sprinkler installation, the fire-extinguishing appliances, means of access to different compartments, decks, etc. the ventilating system, including particulars of the fan control positions, the position of dampers and identification numbers of the ventilating plans serving each station.

■ *Section 4*
General requirements

4.1 The Rules

4.1.1 The Rule requirements are arranged in terms of eight fundamental objectives which all contribute to the overall performance of the fire protection arrangements, *see Vol 3, Pt 3, Ch 2, 4.2 Fire protection objectives 4.2.1* to *Vol 3, Pt 3, Ch 2, 4.2 Fire protection objectives 4.2.1*.

4.1.2 Each of the eight objectives has a series of Rule requirements attributed to them, these Rules are arranged in a 'top-down' manner such that the objective is stated as the highest level requirement. At the next level, a goal, or series of goals, is detailed; the goals are then developed as performance requirements; and ultimately the specified guidance/technical references.

4.1.3 In general, a system is to be compliant with the *SOLAS - International Convention for the Safety of Life at Sea* convention; however, where this cannot be achieved, the performance criteria, goals and objectives are to be satisfied by assignment of a concession or through the application of an Alternative Design Justification Report, *see* the *Naval Survey Guidance*. The referenced*SOLAS - International Convention for the Safety of Life at Sea* regulations to satisfy different goals are provided for guidance purposes. Alternative standards consistent with the overall *SOLAS - International Convention for the Safety of Life at Sea* philosophy can be applied where the compliance with the Objective can be demonstrated to an equivalent level to those in *SOLAS - International Convention for the Safety of Life at Sea*.

4.2 Fire protection objectives

4.2.1 The fire protection objectives to be satisfied by all fire protection systems are as follows:

(a) **Fire Prevention Objective**. Every ship is to be designed and equipped so as to prevent the occurrence of fire or explosion, taking due account of its civil and military operational role, *see Vol 3, Pt 3, Ch 2, 5 Fire prevention*.
(b) **Fire Detection Objective**. Every ship is to be designed and equipped, as far as is practicable, to detect any potentially hazardous fire or explosion, *see Vol 3, Pt 3, Ch 2, 6 Fire detection*.
(c) **Fire Extinguishing Objective**. Every ship is to be equipped, so far as is practicable, so that all detected fires can be safely and effectively extinguished, *see Vol 3, Pt 3, Ch 2, 7 Fire extinguishing*.
(d) **Containment Objective**. Every ship is to be arranged, so far as is practicable, to limit the spread of fire, smoke and toxic by-products to the space of origin, *see Vol 3, Pt 3, Ch 2, 8 Fire and by-product containment*.
(e) **Personnel Hazard Objective**. All reasonable measures are to be taken to prevent hazards to personnel as a result of fire, *see Vol 3, Pt 3, Ch 2, 9 Personnel fire hazards*.
(f) **System Interaction Objective**. The possibility of fire protection measures or systems causing fire related, or non-fire related hazards is to be kept to a level that is as low as is reasonably practicable, *see Vol 3, Pt 3, Ch 2, 10 System interaction*.
(g) **Command and Control Objective**. Suitable means are to be provided to ensure any active fire control measures can be safely and effectively orchestrated, *see Vol 3, Pt 3, Ch 2, 11 Command and control*.
(h) **Structural Integrity Objective**. Sufficient structural integrity is to be maintained following a fire so as to prevent the whole or partial collapse of the ship's structures due to strength deterioration by heat, *see Vol 3, Pt 3, Ch 2, 12 Structural integrity*.

■ *Section 5* Fire prevention

5.1 Fire prevention objective

5.1.1 Every ship is to be designed and equipped so as to prevent the occurrence of fire or explosion, taking due account of its civil and military operational role. The Fire Prevention Goals described in *Vol 3, Pt 3, Ch 2, 5.1 Fire prevention objective 5.1.2* may be achieved by the application of Referenced *SOLAS - International Convention for the Safety of Life at Sea* Regulations which are for guidance purposes. *See also Vol 3, Pt 3, Ch 2, 4.1 The Rules 4.1.3*.

5.1.2 **Fire Prevention Goal 1**. Sources of ignition within the ship are to be kept to a number that is as low as reasonably practicable.

(a) In general, arrangements for items of ignition sources and ignitability are to be in accordance with SOLAS Chapter II-2, Part B, *4 Miscellaneous items of ignition and ignitability*.

5.1.3 **Fire Prevention Goal 2**. The use of combustible and potentially explosive materials is to be restricted and controlled, taking due cognisance of the locality of ignition sources.

(a) Arrangements for fuel oil, lubrication oil and other flammable oils are to be in accordance with SOLAS Chapter II-2, Part B, *2 Arrangements for oil fuel, lubrication oil and other flammable oils*.
(b) Arrangements for gaseous fuel for domestic purposes are to be in accordance with SOLAS Chapter II-2, Part B, *3 Arrangements for gaseous fuel for domestic purposes*.

5.1.4 **Fire Prevention Goal 3**. The fire hazards associated with helicopter facilities are to be as low as reasonably practicable:

In general the arrangements for helicopter facilities are to be in accordance with SOLAS Ch II-2, *Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*.

5.1.5 **Fire Prevention Goal 4**. The fire hazards associated with the carriage of dangerous goods are to be as low as reasonably practicable:

In general the arrangements for the carriage of dangerous goods are to be in accordance with SOLAS Ch II-2, *Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*.

5.1.6 **Fire Prevention Goal 5**. The fire hazards associated with the carriage of vehicles, special category and ro-ro spaces are to be as low as reasonably practicable:

In general the arrangements for the carriage of vehicles, special category and ro-ro spaces are to be in accordance with SOLAS Ch II-2, *Chapter II-2 - Construction - Fire protection, fire detection and fire extinction*.

■ *Section 6* Fire detection

6.1 Fire detection objective

6.1.1 Every ship is to be designed and equipped, as far as is practicable, to detect any potentially hazardous fire or explosion. The Fire Detection Goal described in *Vol 3, Pt 3, Ch 2, 6.1 Fire detection objective 6.1.2* may be achieved by the application of the referenced *SOLAS - International Convention for the Safety of Life at Sea* Regulations which are for guidance purposes. *See also Vol 3, Pt 3, Ch 2, 4.1 The Rules 4.1.3*.

6.1.2 **Fire Detection Goal 1**. Every ship is to be equipped with effective heat/flame and smoke detection systems that will function correctly in the environment in which a fire may be reasonably expected to occur.

(a) In general, the arrangements for detection and alarm are to be in accordance with SOLAS Chapter II-2, Part C, *2 General requirements*.
(b) The testing of fixed fire detection and alarm systems are to be in accordance with SOLAS Chapter II-2, Part C *3 Initial and periodical tests*.
(c) The protection of machinery spaces is to be in accordance with SOLAS Chapter II-2, Part C, *4 Protection of machinery spaces*.
(d) The protection of accommodation, service spaces and control stations is to be in accordance with SOLAS Chapter II-2, Part C, *5 Protection of accommodation and service spaces and control stations*.
(e) The provision of manually operated call points is to be in accordance with SOLAS Chapter II-2, Part C, *7 Manually operated call points*.
(f) Fire patrols are to be arranged in accordance with SOLAS Chapter II-2, Part C, *8 Fire patrols in passenger ships*.
(g) Fire alarm signalling is to be in accordance with SOLAS Chapter II-2, Part C, *9 Fire alarm signalling systems in passenger ships* .

6.1.3 **Fire Detection Goal 2**. Systems are to be arranged so as to detect the re-ignition of a detected and extinguished fire.

■ *Section 7* Fire extinguishing

7.1 Fire extinguishing objective

7.1.1 Every ship is to be equipped, so far as is practicable, so that all detected fires can be safely and effectively extinguished. The Fire Extinguishing Goals described in *Vol 3, Pt 3, Ch 2, 7.1 Fire extinguishing objective 7.1.2* and *Vol 3, Pt 3, Ch 2, 7.1 Fire extinguishing objective 7.1.3* may be achieved by the application of the referenced *SOLAS - International Convention for the Safety*

of Life at Sea Regulations and the technical references which are for guidance purposes. *See also Vol 3, Pt 3, Ch 2, 4.1 The Rules 4.1.3*.

7.1.2 **Fire Extinguishing Goal 1**. Arrangements on board are to be such that all detected fires can be extinguished using a medium which is suitable for the nature of the fire.

(a) Unless given otherwise in the following paragraphs, arrangements for the extinction of fire are to be in accordance with SOLAS Chapter II-2 Part C, *Regulation 10 - Fire fighting*.
(b) Where high pressure sea-water systems are used for fire-fighting purposes, they are to be in accordance with the requirements of *Vol 2, Pt 7, Ch 5, 10 High pressure sea-water systems*.
(c) The water fire-fighting system is to have a capacity, equal to the requirements of HPSW systems as outlined in *Vol 2, Pt 7, Ch 5, 10.2 Pump units 10.2.3*.
(d) The number and position of hydrants are to be such that at least two jets of water not emanating from the same hydrant, one of which shall be from a single length of hose, may reach any part of the ship where a fire can be reasonably expected. Such hydrant is to be located near the access to protected spaces. Hydrants for boundary cooling for the expected fire scenarios are also to be made available.
(e) With regard to pressure at hydrants, the water fire-fighting system is to be capable of delivering the required quantity of water at adjacent hydrants with the following pressures being available at all hydrants:

- 4 bar for NS1 and NS2 ships and all ships of 4000 gross tonnage or greater.
- 3 bar for NS3 ships.

The pressure is not to exceed that for which the system has been designed, or that which the fire hose cannot be demonstrated as being controllable.

(f) With regard to the provision of fire pumps, ships of 4000 gross tonnage and above are to be fitted with at least three fire pumps, and ships of less than 4000 gross tonnage are to be fitted with at least two. If the pumps are arranged such that a single fire will put all pumps out of action, an additional emergency fire pump will be required.
(g) With regard to the requirements for fire hoses, at least one fire hose of the required length is to be permanently available at each required hydrant. These are to be for the sole use of fire-fighting and testing the equipment.
(h) With regard to sprinkler systems, NS1 and NS2 ships, and those designed to carry in excess of 50 embarked personnel, are to be fitted with an automatic sprinkler, fire detection and fire alarm system in accordance with the FSS Code or other agreed specified standard in all control stations, accommodation and service spaces. Alternatively, if a water sprinkler system may cause damage to Mobility and/or Ship Type equipment an agreed alternative fixed fire-fighting system is to be specified. Spaces where there is little or no risk of fire need not be fitted with such a system.
(i) On NS3 ships and vessels designed to carry less than 50 embarked personnel, an automatic sprinkler, fire detection and fire alarm system in accordance with the FSS Code or other agreed specified standard is to be installed to protect control stations. A fixed fire detection system and alarm is to be arranged to provide smoke detection in corridors, stairways, escape and access routes within accommodation spaces.
(j) With regard to fire-fighters' outfits, the fire-fighters' outfit is to be to a standard acceptable to the Naval Authority. As a minimum they are to be in accordance with the Fire Safety Systems Code (FSS Code).
(k) Each ship is to carry sufficient fire-fighters' outfits for the number required for each fire party as agreed with the Naval Authority. Each ship is to carry at least two firefighters' outfits. Two fire-fighters' outfits are to be provided for every 80 m of longitudinal deck space and in addition, two in every vertical zone. One water fog applicator is to be stored adjacent to each set of breathing apparatus. The fire-fighters' outfits and fog applicators are to be readily accessible in each fire zone.
(l) Where water is used for fire-fighting purposes in any compartment, these compartments are to be provided with arrangements for removing the water after fire extinguishing.

7.1.3 **Fire Extinguishing Goal 2**. The capacity of the extinguishing system is to be sufficient to extinguish any fire which may reasonably be expected to occur within the jurisdiction of that extinguishing system.

With regard to the availability of water, at least one effective jet of water is to be immediately available from any hydrant in an interior space. The continued supply of that water is to be ensured by the automatic starting of a fire pump.

Section 8
Fire and by-product containment

8.1 Fire and by-product containment objective

8.1.1 Every ship is to be arranged, so far as is practicable, to limit the spread of fire, smoke and toxic by-products to the space of origin. The Fire and By-Product Containment Goal in *Vol 3, Pt 3, Ch 2, 8.1 Fire and by-product containment objective 8.1.2* may be achieved by the application of the referenced *SOLAS - International Convention for the Safety of Life at Sea* Regulations and the technical references which are provided for guidance purposes. *See also Vol 3, Pt 3, Ch 2, 4.1 The Rules 4.1.3*.

8.1.2 **Fire and By-product Containment Goal 1**. Adequate containment boundaries are to be fitted within the ship in order that spread of fire, smoke and toxic by-products is limited to a predetermined area, consistent with allowing as near normal operation of the vessel as practically possible in the event of fire, without evacuation.

(a) Arrangements for the containment of fire are to be in accordance with SOLAS Chapter II-2, Part C, *Regulation 9 - Containment of fire*.
(b) Control of air supply and flammable liquid to the space is to be in accordance with SOLAS Chapter II-2, Regulations Part B, *2 Control of air supply and flammable liquid to the space* and Part C, *2 Protection of control stations outside machinery spaces*.
(c) With regard to closing devices, vessels designed to carry in excess of 50 embarked personnel, power ventilation, except in machinery spaces and control stations not having an exit to an open deck, is to be fitted with controls so that all fans can be stopped from either of two positions which should be located as far apart from each other as is practicable.
(d) All controls for the fire-extinguishing system shall be situated in one control position or in as few positions as possible.
(e) The use of fire protection materials is to be in accordance with SOLAS Chapter II-2, Part B, *3 Fire protection materials*.
(f) The arrangements for the control of smoke spread are to be in accordance with SOLAS Chapter II-2 Part C, *Regulation 8 - Control of smoke spread*.

8.1.3 Where the Separate Machinery Spaces ★ Enhancement notation is selected, the requirements of *Vol 1, Pt 1, Ch 2, 3.9 Machinery and Engineering Systems notations* are also applicable.

Section 9
Personnel fire hazards

9.1 Personnel hazard objective

9.1.1 All reasonable measures are to be taken to prevent hazards to personnel as a result of fire. The Personnel Hazard Goals in *Vol 3, Pt 3, Ch 2, 9.1 Personnel hazard objective 9.1.2* and *Vol 3, Pt 3, Ch 2, 9.1 Personnel hazard objective 9.1.3* may be achieved by the application of the referenced *SOLAS - International Convention for the Safety of Life at Sea* Regulations which are provided for guidance purposes. See also *Vol 3, Pt 3, Ch 2, 4.1 The Rules 4.1.3*.

9.1.2 **Personnel Hazard Goal 1**. Where materials used or carried may develop vapours and smoke dangerous to personnel, the ship is to be arranged so as to minimise the effects from those vapours and smoke.

The potential for smoke generation and its toxicity is to be in accordance with SOLAS Chapter 2, Part B, *Regulation 6 - Smoke generation potential and toxicity*.

9.1.3 **Personnel Hazard Goal 2**. Where personnel may be reasonably expected to fight a fire, there is to be adequate provision of protective equipment for each member of the fire-fighting party. The equipment is to be of a standard applicable for its intended application.

Fire-fighters' outfits are to be in accordance with SOLAS Chapter II-2, Part C, *10 Fire-fighter's outfits*, *see Vol 3, Pt 3, Ch 2, 7.1 Fire extinguishing objective 7.1.2* and *Vol 3, Pt 3, Ch 2, 7.1 Fire extinguishing objective 7.1.2*.

■ Section 10 System interaction

10.1 System interaction objective

10.1.1 The possibility of fire protection measures or systems causing fire related, or non-fire related hazards is to be kept to a level that is as low as is reasonably practicable.

10.1.2 **System Interaction Goal**. Systems are to be designed, as far as is practicable, to ensure that the operation of that system will not inadvertently degrade the performance of any other system.

■ Section 11 Command and control

11.1 Command and control objective

11.1.1 Suitable means are to be provided to ensure any active fire control measures can be safely and effectively orchestrated.

11.1.2 **Command and Control Goal 1**. Fire control stations are to be provided so that there can be a central point of command in all fire situations where fire-fighting may be expected.

11.1.3 **Command and Control Goal 2**. Fixed means of two-way speech communication are to be provided between the fire-fighting control station and identified fire risk areas.

■ Section 12 Structural integrity

12.1 Structural integrity objective

12.1.1 Sufficient structural integrity is to be maintained following a fire so as to prevent the whole or partial collapse of the ship's structures due to strength deterioration by heat. The Structural Integrity Goal in *Vol 3, Pt 3, Ch 2, 12.1 Structural integrity objective 12.1.2* may be achieved by the application of the referred *SOLAS - International Convention for the Safety of Life at Sea* Regulation which is provided for guidance purposes. *See also Vol 3, Pt 3, Ch 2, 4.1 The Rules 4.1.3*.

12.1.2 **Structural Integrity Goal**. Materials used in the construction of the ship's structure are to ensure that structural integrity is not degraded due to fire.

The arrangements for structural integrity following fire are to be in accordance with SOLAS Chapter II-2, Part C, *Regulation 11 - Structural integrity*. *See also Vol 1, Pt 4, Ch 1, 4.2 Use of aluminium alloys*.

■ *Section 1* Scope

1.1 Philosophy

1.1.1 The purpose of this Chapter is to provide a methodology for confirming that a naval ship's crew and embarked personnel can escape from any space within the ship to a designated place of safety in a safe, timely and effective manner as the need arises. It also provides a method for confirming that access to essential areas is available for personnel and equipment required for damage control and fire fighting purposes.

1.1.2 The Objectives of this Chapter as defined in *Vol 3, Pt 3, Ch 3, 4.2 Escape of personnel and emergency access arrangements objectives* are to be realised through the content of these Rules that aim to ensure the provision of sufficient equipment and arrangements to enable the removal of all personnel to a designated place of safety until such a time that they can be evacuated from the ship and to ensure adequate emergency access.

1.1.3 In general, demonstration of satisfactory escape arrangements will be achieved through compliance with the relevant requirements of SOLAS Chapter II-2, *Regulation 13 - Means of escape*. Where escape arrangements deviate from the technical requirements of *SOLAS - International Convention for the Safety of Life at Sea* they are to be suitable to satisfy the functional requirements, escape objective and goals of this Chapter.

1.1.4 Demonstration of acceptable emergency access arrangements will be achieved by satisfactory demonstration of the emergency access objective and associated goal.

1.1.5 This Chapter of the Rules is to be read in conjunction with *Vol 3, Pt 3, Ch 1 General Requirements* of the Rules for Naval Ships.

1.1.6 *See also Vol 3, Pt 3, Ch 4 Life-Saving and Evacuation Arrangements* of this Part of the Rules.

1.2 Application

1.2.1 The requirements in this Chapter of the Rules are to be applied where a Certificate of Compliance or Class Notation for Escape and Emergency Access **ESC** is requested.

1.2.2 The 'Star endorsement' (★) will be assigned to vessels where the arrangements on board are in accordance with stated National Administration requirements. This does not necessarily denote automatic endorsement by the National Administration.

1.2.3 The 'Double Star endorsement' (★★) will be assigned to vessels where the arrangements on board are in accordance with stated Naval Administration requirements and *ANEP-77 NATO Naval Ship Code* (NSC) – Chapter VII Escape, Evacuation and Rescue. This does not necessarily denote automatic endorsement by the Naval Administration.

■ *Section 2*
Classification requirements for escape and emergency access

2.1 General requirements - SOLAS

2.1.1 The Escape and Emergency Access **ESC** notation will be assigned to vessels which can demonstrate that the levels of personnel safety in the event of a 'prepare to evacuate' scenario are in accordance with *Vol 3, Pt 3, Ch 3, 3 Documentation required for design review* with these Rules.

2.1.2 Where the **ESC** notation is to be assigned, an **LMC** notation must have been assigned, *see Vol 3, Pt 3, Ch 1, 1.1 Application 1.1.2*.

2.2 General requirements – NSC

2.2.1 The Escape and Emergency Access **ESC★★** notation will be assigned to vessels which can demonstrate that the levels of personnel safety in the event of a 'prepare to evacuate' scenario are in accordance with Chapter VII of the NSC.

2.2.2 Where the **ESC★★** notation is to be assigned, a **LSAE** and an **LMC** notation must also have been assigned, *see Vol 3, Pt 3, Ch 1, 1.1 Application 1.1.2*.

■ *Section 3*
Documentation required for design review

3.1 System Operational Concept

3.1.1 The design intent of any escape and emergency access arrangements is to be submitted in the form of a System Operational Concept and is to include, but not be limited to:

(a) The required class notation, **ESC**, **ESC★** or **ESC★★**. If a military distinction (**MD**) notation is required this is also to be declared, *see Vol 1, Pt 1, Ch 2, 3.8 Military Distinction notations*.
(b) Details of the intended mode of operation of escape and emergency access systems/equipment to include environmental conditions together with a description of any escape and emergency access scenarios and their development and application in the design.
(c) Manning levels and operator competencies/authorisations required.
(d) Indication of whether or not alternative design assessment is being sought, if the proposed design deviates from the specified guidance identified in these Rules.

The System Operational Concept is to be agreed by the designer and Owner, *see also Vol 3, Pt 3, Ch 1, 2.3 Documentation required for design review 2.3.2*.

3.2 Design disclosure

3.2.1 In addition to submission of an acceptable System Operational Concept, a Design Disclosure is required for submission to and acceptance by LR. The Design Disclosure is to include, but is not limited to:

(a) A description of the escape regime, i.e. estimated times to designated places of safety in all foreseeable conditions. This is also to include a declaration of all designated places of safety.
(b) A statement of all design standards used in the design, manufacture, installation and testing of escape and emergency access systems.
(c) A proposed list of all surveyable items together with any additional recommendations from equipment/component manufacturers. Evidence is also to be provided that all surveyable items of equipment have approval certificates.
(d) Details of the proposed survey and maintenance regime.
(e) Evidence of compliance with the Objectives and Goals defined in *Vol 3, Pt 3, Ch 3, 5 Escape of personnel* and *Vol 3, Pt 3, Ch 3, 6 Emergency access*. This may be in the form of compliance with any specified guidance, Concessions, Alternative Design Justification Reports or an acceptable combination of all three. *See also Vol 3, Pt 3, Ch 1, 2.3 Documentation required for design review* and *Vol 3, Pt 3, Ch 6 Pollution Prevention*.

(i) If applying for SOLAS, follow *Vol 3, Pt 3, Ch 3, 5 Escape of personnel* and *Vol 3, Pt 3, Ch 3, 6 Emergency access*;
(ii) If applying for NSC, follow *Vol 3, Pt 3, Ch 3, 6 Emergency access*.

(f) Details of the Hazard Identification process and Class related hazards are to be submitted. A hazard identification system is to be in place at the design stage whereby all hazards identified are recorded. If application of these Rules has been identified as a hazard avoidance/mitigation measure, then details are to be submitted.
(g) Details of equipment configurations that are safe for operators and users.
(h) Details of the proposed test procedure required to demonstrate functionality at the time of commissioning.

See also Vol 3, Pt 3, Ch 1, 2.3 Documentation required for design review and *Vol 3, Pt 3, Ch 6 Pollution Prevention*

3.3 Plans

3.3.1 To support the Design Disclosure and for the purposes of assessing compliance with design requirements, for inspection, installation and testing; guidance on the plans and information to be submitted for assessment and review are detailed in *Vol 3, Pt 3, Ch 3, 3.3 Plans 3.3.2*

3.3.2 For escape equipment, the following plans and information:

(a) Certificates of conformity.
(b) General arrangement plans of equipment, detailing all essential parameters, weights, safe working loads, etc.

3.3.3 For arrangements of equipment, the following plans and information:

(a) General arrangement plans of equipment layout, showing place of safety points, equipment stowage points, escape and access routes etc.

3.3.4 For deployment and operational procedures, the following information:

(a) Details of the deployment and operation of equipment.

■ *Section 4*
General requirements

4.1 The Rules

4.1.1 The Rule requirements are arranged in terms of two fundamental objectives which both contribute to the overall performance of the escape and emergency access arrangements, *see Vol 3, Pt 3, Ch 3, 4.2 Escape of personnel and emergency access arrangements objectives*.

4.1.2 Each of the two objectives has a series of Rule requirements attributed to them, these Rules are arranged in a 'top-down' manner such that an objective is stated as the highest level requirement. At the next level, a goal, or series of goals, are detailed; the goals are then developed as performance requirements; and ultimately specified guidance where applicable.

4.1.3 In general, a system is to be compliant with the *SOLAS - International Convention for the Safety of Life at Sea* convention; however where this cannot be achieved, the performance criteria, goals and objectives are to be satisfied by assignment of a Concession or through the application of an Alternative Design Justification Report, *see* the *Naval Survey Guidance*. The referenced *SOLAS - International Convention for the Safety of Life at Sea* Regulations to satisfy different Goals are provided for guidance purposes. Alternative standards consistent with the overall SOLAS philosophy can be applied where the compliance with the Objective can be demonstrated to an equivalent level as those in SOLAS.

4.1.4 The escape routes are to be designed so as to support escape of all personnel to a designated place of safety. Where a pre-determined time for escape is specified in the Design Disclosure, based on the design and operational role of the ship then it is to be validated by full-scale trials or by a simulation acceptable to LR and the Naval Administration.

4.2 Escape of personnel and emergency access arrangements objectives

4.2.1 The escape and emergency access arrangements objectives to be satisfied by all escape and emergency access systems and arrangements are as follows;

(a) **Escape of Personnel Objective**. Every ship is to be arranged so that all spaces have means of safe and effective escape for personnel to a designated place of safety, during anticipated emergency situations, *see Vol 3, Pt 3, Ch 3, 5 Escape of personnel*.
(b) **Emergency Access Objective**. Every ship is to be arranged so that personnel can access all areas with necessary equipment, for damage control and fire-fighting purposes and exercises, *see Vol 3, Pt 3, Ch 3, 6 Emergency access*.

■ *Section 5*
Escape of personnel

5.1 Escape objective

5.1.1 Every ship is to be arranged so that all spaces have a means of safe and effective escape for personnel to a designated place of safety, during anticipated emergency situations. The Escape Goals described in *Vol 3, Pt 3, Ch 3, 5.1 Escape objective 5.1.2* may be achieved by the application of the referenced *SOLAS - International Convention for the Safety of Life at Sea* Regulations which are for guidance purposes. *See also Vol 3, Pt 3, Ch 3, 4.1 The Rules 4.1.3*.

5.1.2 **Escape Goal 1**. All escape routes are to provide for effective and obvious access to designated places of safety.

(a) In general the provision of escape routes on all ships is to be in accordance with SOLAS Chapter II-2, Regulations *1 Purpose*.
(b) In general escape routes from machinery spaces on all ships are to be in accordance with SOLAS Chapter II-2, *4 Means of escape from machinery spaces*.
(c) In general escape route arrangements for ro-ro spaces are to be in accordance with SOLAS Chapter II-2, Regulations *5 Means of escape on passenger ships from special category and open ro-ro spaces to which any passengers carried can have access*.

5.1.3 **Escape Goal 2**. All escape routes are to be readily accessible.

5.1.4 **Escape Goal 3**. All escape routes are to be free from undue hazards.

5.1.5 **Escape Goal 4**. Physical dimensions of escape routes are to be suitable for the anticipated flow of personnel during all foreseeable emergency conditions.

(a) In general the dimensions and design of escape routes are to be in accordance with SOLAS Chapter II-2, *Regulation 13 - Means of escape*.

5.1.6 **Escape Goal 5**. Personnel are to be adequately protected from fire, smoke and hazardous vapours while escaping.

5.1.7 **Escape Goal 6**. The escape arrangements for individual compartments are to be suitable for the purpose of the compartment and its intended occupants.

■ *Section 6*
Emergency access

6.1 Emergency access objective

6.1.1 Every ship is to be arranged so that personnel can access all areas with necessary equipment, for damage control and fire-fighting purposes and exercises.

6.1.2 **Emergency Access Goal 1**. Provisions for emergency access are to be arranged such that they do not contribute to the spread of fire, flood, smoke or other toxic gases to the designated places of safety.

Life-Saving and Evacuation Arrangements

■ *Section 1* **Scope**

1.1 Philosophy

1.1.1 The purpose of this Chapter is to provide a methodology for confirming that a naval ship can be evacuated in a safe and effective manner as the need arises, and that personnel can be effectively rescued from the water.

1.1.2 The objectives of this Chapter as defined in *Vol 3, Pt 3, Ch 4, 4.2 Life-saving and evacuation arrangements objectives* are to be achieved through the content of these Rules that aim to ensure the provision of sufficient equipment to evacuate all personnel to a place of safety until such a time that they can be rescued, and to ensure that adequate equipment is provided to rescue personnel from the water.

1.1.3 In general, demonstration of adequate provision of life-saving and rescue equipment will be achieved through compliance with the relevant requirements of *Chapter III - Life-saving appliances and arrangements* or *ANEP-77 NATO Naval Ship Code* (NSC). Where life-saving and rescue arrangements deviate from the requirements of *Chapter III - Life-saving appliances and arrangements*, they are to be suitable to satisfy the life saving and rescue objectives and functional requirements of this Chapter.

1.1.4 This Chapter is to be read in conjunction with *Vol 3, Pt 3, Ch 1 General Requirements*.

1.2 Application

1.2.1 The requirements in this Chapter are to be applied where a Certificate of Compliance or Class Notation for Life-Saving and Evacuation Arrangements **LSAE** is requested.

1.2.2 The 'Star endorsement' (★) will be assigned to vessels where the arrangements on board are in accordance with stated National Administration requirements. This does not necessarily denote automatic endorsement by the National Administration.

1.2.3 The 'Double Star endorsement' (★★) will be assigned to vessels where the arrangements on board are in accordance with stated Naval Administration requirements and *ANEP-77 NATO Naval Ship Code* (NSC) – Chapter VII Escape, Evacuation and Rescue. This does not necessarily denote automatic endorsement by the Naval Administration.

■ Section 2
Requirements for life-saving and evacuation arrangements

2.1 General requirements - SOLAS

2.1.1 The Life-Saving and Evacuation Arrangements **LSAE** notation will be assigned to vessels which demonstrate that the provision of life-saving and rescue equipment on board are in accordance with *Vol 3, Pt 3, Ch 4, 3 Documentation required for design review* of these Rules.

2.1.2 Where the **LSAE** notation is to be assigned, an **LMC** notation must have been assigned, *see Vol 3, Pt 3, Ch 1, 1.1 Application 1.1.2*.

2.2 General requirements – NSC

2.2.1 The Life-Saving and Evacuation Arrangements **LSAE★★** notation will be assigned to vessels which can demonstrate that the levels of personnel safety in the event of a 'prepare to evacuate' scenario are in accordance with Chapter VII of the NSC.

2.2.2 Where the **LSAE★★** notation is to be assigned, an **ESC** and a **LMC** notation must also have been assigned, *see Vol 3, Pt 3, Ch 1, 1.1 Application 1.1.2*.

■ Section 3
Documentation required for design review

3.1 System Operational Concept

3.1.1 The design intent of any life-saving or rescue system is to be submitted in the form of a System Operational Concept and is to include, but not be limited to:

(a) The required class notation, **LSAE**, **LSAE★** or **LSAE★★**. If a military distinction (**MD**) notation is required this is to be declared, *see Vol 1, Pt 1, Ch 2, 3.8 Military Distinction notations*.
(b) Details of the intended mode of operation of life-saving and evacuation systems/equipment to include environmental conditions together with a description of any emergency scenarios and their development and application in the design.
(c) Manning levels and Operator competencies/authorisations required.
(d) Indication of whether or not alternative design assessment is being sought, if the proposed design deviates from the specified guidance identified in these Rules.

The System Operational Concept is to be agreed by the designer and Owner, *see also Vol 3, Pt 3, Ch 1, 2.3 Documentation required for design review*.

3.2 Design disclosure

3.2.1 In addition to submission of an acceptable System Operational Concept, a Design Disclosure is required for submission to and acceptance by Lloyd's Register (hereinafter referred to 'LR'). The Design Disclosure is to include, but is not limited to:

(a) A statement of all design standards used in the design, manufacture, installation and testing of life-saving and rescue equipment.
(b) A proposed list of all surveyable items together with any additional recommendations from equipment/component manufacturers. Evidence is also to be provided that all surveyable items of equipment have approval certificates.
(c) Details of the proposed survey and maintenance regime.
(d) Evidence of compliance with the objectives and goals defined in *Vol 3, Pt 3, Ch 4, 5 Evacuation of personnel*. This may be in the form of*Vol 3, Pt 3, Ch 6 Pollution Prevention* compliance with specified guidance, Concessions, Alternative Design Justification Reports or an acceptable combination of all three, *see also Vol 3, Pt 3, Ch 1, 2.3 Documentation required for design review* and *Vol 3, Pt 3, Ch 1, 6 Route to conformance*.
(e) Details of the Hazard Identification process and Class related hazards are to be submitted. A hazard identification system is to be in place at the design stage whereby all hazards identified are recorded. If application of these Rules has been identified as a hazard avoidance/mitigation measure, then details are to be submitted.

(f) Details of equipment configurations that are safe for Operators and users.
(g) Details of the proposed test procedure required to demonstrate functionality at the time of commissioning.

3.3 Documents required for design review

3.3.1 To support the design disclosure and for the purposes of assessing compliance with design requirements for inspection, installation and testing; guidance on the plans and information to be submitted for assessment and review are detailed in *Vol 3, Pt 3, Ch 4, 3.3 Documents required for design review 3.3.2*.

3.3.2 For life-saving appliances, the following plans and information:

(a) Certificates of conformity against the International Life Saving Appliance Code (MSC Res. 48(66)) or other specified standard acceptable to the Naval Administration and LR.
(b) General arrangement plans of equipment, detailing all essential parameters, weights, Safe Working Loads, etc.

3.3.3 For arrangements of equipment, the following plans:

(a) General arrangement plans of equipment layout, showing embarkation points, equipment stowage points, etc.
(b) General arrangement plans of all equipment assemblies such as davits, reeving arrangements, etc.

3.3.4 For operational procedures, the following information:

(a) Details of the evacuation procedure, to include drills and training.
(b) An evacuation analysis in accordance with SOLAS Chapter II-2, *4 Protection of machinery spaces* or NSC Chapter VII, Regulation 3 as applicable.

■ *Section 4*
General requirements

4.1 The Rules

4.1.1 The requirements are arranged in terms of four fundamental objectives which all contribute to the overall performance of the life-saving and evacuation arrangements, *see Vol 3, Pt 3, Ch 4, 4.2 Life-saving and evacuation arrangements objectives*.

4.1.2 Each of the four objectives has a series of Rule requirements attributed to them, these Rules are arranged in a 'top-down' manner such that the objective is stated as the highest level requirement. At the next level, a goal or series of goals, are detailed; the goals are then developed as performance requirements; and ultimately specified guidance where applicable.

4.1.3 In general, a system is to be compliant with the *SOLAS - International Convention for the Safety of Life at Sea* convention; however, where this cannot be achieved, the performance criteria, goals and objectives are to be satisfied by assignment of a Concession or through the application of an Alternative Design Justification Report, *see* the *Naval Survey Guidance*. The referenced *SOLAS - International Convention for the Safety of Life at Sea* Regulations to satisfy different Goals are provided for guidance purposes. Alternative standards consistent with the overall *SOLAS - International Convention for the Safety of Life at Sea* philosophy can be applied where the compliance with the objective can be demonstrated to an equivalent level to those in *SOLAS - International Convention for the Safety of Life at Sea*.

4.1.4 These Rules are based on the requirements of SOLAS *Chapter III - Life-saving appliances and arrangements* and all terms and definitions are referenced therein. All references to the Code refer to the *LSA Code - International Life-Saving Appliance Code – Resolution MSC.48(66)* .

4.1.5 The evacuation systems are to be designed so as to support evacuation of all personnel in a pre-determined time. Where a pre-determined time for evacuation is specified, based on the design and operational role of the ship then it is to be validated by full-scale trials or by a simulation acceptable to LR and the Naval Administration.

4.2 Life-saving and evacuation arrangements objectives

4.2.1 The objectives to be satisfied by all life-saving and evacuation systems are as follows:

(a) **Evacuation Objective**. Arrangements are to be provided to enable personnel to evacuate the ship safely and in a specified time, *see Vol 3, Pt 3, Ch 4, 5 Evacuation of personnel*.

(b) **Personnel Protection Objective**. Evacuated personnel are to be kept protected until such time as they can be rescued from the survival craft, *see Vol 3, Pt 3, Ch 4, 6 Personnel protection*.

(c) **Rescue Objective**. Every ship is to be suitably equipped to rescue personnel from the water, *see Vol 3, Pt 3, Ch 4, 7 Rescue of personnel*.

(d) **Command and Control Objective**. Every ship is to be equipped and manned so that command of all evacuation and life-saving situations can be maintained, *see Vol 3, Pt 3, Ch 4, 8 Command and control*.

■ *Section 5* Evacuation of personnel

5.1 Evacuation objective

5.1.1 Arrangements are to be provided to enable personnel to evacuate the ship safely and in a specified time. The Evacuation Goals described in*Vol 3, Pt 3, Ch 4, 5.1 Evacuation objective 5.1.2* may be achieved by the application of the referred *SOLAS - International Convention for the Safety of Life at Sea* Regulations and technical references which are for guidance purposes. *See also Vol 3, Pt 3, Ch 4, 4.1 The Rules 4.1.3*.

5.1.2 **Evacuation Goal 1**. Life-saving equipment is to be arranged on the vessel in such a manner that it is easily accessible and readily deployed in the case of an emergency.

(a) In general, the provision of life jackets is to be in accordance with SOLAS Chapter III, Part B, *2 Lifejackets*.

(b) Arrangements for life-saving and evacuation equipment are to be in accordance with SOLAS Chapter III, Part B, *Regulation 11 - Survival craft muster and embarkation arrangements* , *Regulation 12 - Launching stations* , *Regulation 13 - Stowage of survival craft* , *Regulation 15 - Stowage of marine evacuation systems* and *Regulation 16 - Survival craft launching and recovery arrangements* , as applicable.

(c) Arrangements for operational readiness are to be in accordance with SOLAS, Part B, Chapter III, *Regulation 20 - Operational readiness, maintenance and inspections* .

5.1.3 **Evacuation Goal 2**. The total capacity of the ship's survival craft is to be sufficient to ensure that all personnel can be evacuated during foreseeable emergency conditions:

The provision of survival craft and rescue boats is to be in accordance with SOLAS Part B, Chapter III, *Regulation 31 - Survival craft and rescue boats* .

5.1.4 **Evacuation Goal 3**. All life-saving and rescue equipment is to be of an approved type to specified standards:

(a) In general, all life-saving and rescue equipment prototypes are to be tested to confirm that they comply with the International Life Saving Appliance Code or other standard acceptable to LR, the Naval Administration or National Administration.

(b) All life-saving and rescue equipment is to be subject to production tests to ensure that they are constructed to the same standard as the approved prototype.

5.1.5 **Evacuation Goal 4**. Provision is to be made to ensure that the deployed survival craft can be moved to safety from a damaged vessel until such time all personnel can be rescued.

5.1.6 **Evacuation Goal 5**. Provision is to be made for incapacitated people to be evacuated to safety.

■ *Section 6* Personnel protection

6.1 Personnel protection objective

6.1.1 Evacuated personnel are to be kept protected until such time as they can be rescued from the survival craft. The Personnel Protection Goal described in *Vol 3, Pt 3, Ch 4, 6.1 Personnel protection objective 6.1.2* may be achieved by the application of the referenced *SOLAS - International Convention for the Safety of Life at Sea* Regulation which is for guidance purposes. *See also Vol 3, Pt 3, Ch 4, 4.1 The Rules 4.1.3*.

6.1.2 **Personnel Protection Goal 1**. Evacuated personnel are to be protected from the adverse effects of the environment such as hypothermia or exposure:

(a) In general, the provision of immersion suits and anti-exposure suits is to be consistent with SOLAS Chapter III, Part B, *3 Immersion suits and anti-exposure suits*.

6.1.3 **Personnel Protection Goal 2**. Survival craft are to be equipped with sufficient provisions to keep personnel free from starvation and dehydration for a specified period of time.

■ *Section 7*
Rescue of personnel

7.1 Rescue of personnel objective

7.1.1 Every ship and its life saving equipment are to be suitably equipped to locate and rescue personnel from the water. The rescue of Personnel Goals described in *Vol 3, Pt 3, Ch 4, 7.1 Rescue of personnel objective 7.1.2* may be achieved by the application of the referenced *SOLAS - International Convention for the Safety of Life at Sea* Regulations which are for guidance purposes. *See also Vol 3, Pt 3, Ch 4, 4.1 The Rules 4.1.3*.

7.1.2 **Rescue of Personnel Goal 1**. Every ship is to be designed to prevent the risk of an accidental man overboard situation as far as is practicable:

(a) Line throwing appliances are to be in accordance with SOLAS Part B, Chapter III, *Regulation 18 - Line-throwing appliances* .
(b) In general, the provision of life buoys on all ships is to be in accordance with SOLAS Chapter III, Part B, *1 Lifebuoys*. With regard to the marking of life buoys, all life buoys are to be marked with the ship's identification number.

7.1.3 **Rescue of Personnel Goal 2**. Every ship is to be suitably equipped for the mass rescue of personnel from the water, on board:

(a) Rescue boat launching and recovery arrangements are to be in accordance with SOLAS Part B, Chapter III, *Regulation 17 - Rescue boat embarkation, launching and recovery arrangements* .
(b) Rescue boats are to be stowed in accordance with SOLAS, Part B, Chapter III, *Regulation 14 - Stowage of rescue boats* .

7.1.4 **Rescue of Personnel Goal 3**. Every ship and its survival craft is to be fitted with equipment to ensure that the ship and its survival craft can be efficiently located and retrieved as necessary:

(a) Each ship is to be fitted with at least one radar transponder on both sides. The radar transponders are to be located such that they can be readily deployed on any survival craft, other than the life rafts.
(b) The provision of flares is to be in accordance with SOLAS Chapter III, Part B, *Regulation 6 - Communications* .

■ *Section 8*
Command and control

8.1 Command and control objective

8.1.1 Suitable means are to be provided to ensure that life-saving and evacuation operations can be safely and effectively orchestrated. The Command and Control Goals described in *Vol 3, Pt 3, Ch 4, 8.1 Command and control objective 8.1.2* may be achieved by the application of the referenced *SOLAS - International Convention for the Safety of Life at Sea* Regulations which are for guidance purposes. *See also Vol 3, Pt 3, Ch 4, 4.1 The Rules 4.1.3*.

8.1.2 **Command and Control Goal 1**. Every ship is to be equipped and manned so that command of all life-saving and evacuation situations can be maintained:

(a) Every ship is to be fitted with a general emergency alarm in accordance with SOLAS Chapter III, Part B, *Regulation 6 - Communications* , as applicable. The alarm is to be audible on all open decks and every compartment.
(b) Every ship is to be fitted with a public address system in accordance with SOLAS Chapter III, Part B, *Regulation 6 - Communications* .

(c) Emergency situation instructions are to be in accordance with SOLAS Chapter III, Part B, *Regulation 8 - Muster list and emergency instructions* and *Regulation 9 - Operating instructions* .

(d) The manning and supervision of life saving appliances are to be in accordance with SOLAS Chapter III, Part B, *Regulation 10 - Manning of survival craft and supervision* .

(e) Emergency and training drills are to be in accordance with SOLAS Part B, Chapter III, *Regulation 19 - Emergency training and drills* .

8.1.3 **Command and Control Goal 2.** Reliable means of speech communication are to be provided between the central point of command and strategic life-saving and evacuation stations:

Two-way VHF radiotelephone apparatus is to be provided on every ship.

■ *Section 1* Scope

1.1 Philosophy

1.1.1 The purpose of this Chapter is to provide a methodology for confirming that the arrangements on board a naval ship provide for navigation and communication equipment and arrangements which provide for safe and effective task performance and to meet the requirements of international regulations.

1.1.2 The objectives of this Chapter as defined in *Vol 3, Pt 3, Ch 5, 4.2 Safety of navigation and communications objectives* are to be realised through the content of these Rules that detail the functional requirements that are to be met by the ship's navigation and communication systems.

1.1.3 In general, demonstration of satisfactory levels of safety of navigation and communication will be achieved through compliance with the relevant requirements of these Rules and the documents referenced therein. Where navigation and communication arrangements deviate from the technical requirements of this chapter they are to be suitable to satisfy the objectives of and goals of this Chapter.

1.1.4 In addition to the requirements for ships to be furnished with the necessary equipment for effective navigation and communication, SOLAS requires the contracting Governments to provide certain shore-based facilities and services. These services assist the ships in maintaining effective navigation and communication. It is beyond the scope of these Rules to mandate that a Government is to provide such services, however it must be noted that they are an essential part of the ship's operation.

1.1.5 The requirements placed on the contracting Governments can be found in SOLAS *Part B - Undertakings by Contracting Governments1* Part B and Chapter V *Regulation 4 - Functional requirements1* inclusive, and *Regulation 31 - Danger messages*.

1.2 Application

1.2.1 The requirements of this Chapter are to be read in conjunction with *Vol 3, Pt 3, Ch 1 General Requirements*.

1.2.2 The requirements in this Chapter of the Rules are to be applied where a Certificate of Compliance or Class Notation for Safety of Navigation and Communication (**SNC**) is requested.

1.2.3 The 'Star' Endorsement' (★) will be assigned to vessels where the arrangements on board are acceptable to the National Administration for regulating safety of navigation and communications requirements for a particular ship.

■ Section 2
Classification requirements for safety of navigation and communication systems

2.1 General requirements

2.1.1 The Safety of Navigation and Communication **SNC** notation will be assigned to vessels that demonstrate that the levels of navigation and communication are in accordance with these Rules.

2.1.2 No provision in these Rules is to prevent the use by any ship, survival craft or person in distress, of any means at their disposal to attract attention, make known their position and obtain help.

2.1.3 The Requirements of this Chapter are based on those of SOLAS *Chapter IV - Radiocommunications* and *Chapter V - Safety of navigation*, and the terms and definitions referenced therein are to be referred to.

2.1.4 Where the **SNC** notation is to be assigned, an **LMC** notation must have been assigned, *see Vol 3, Pt 3, Ch 1, 1.1 Application 1.1.2*.

■ Section 3
Documentation required for design review

3.1 System Operational Concept

3.1.1 The design intent of any communications and navigation system is to be submitted in the form of a System Operational Concept and is to include but not be limited to:

(a) The required class notation, **SNC** or **SNC★**. If a military distinction (**MD**) notation is required this is also to be declared. *See Vol 1, Pt 1, Ch 2, 3.8 Military Distinction notations*.
(b) Details of the intended mode of operation of navigation and communication systems/equipment including environmental conditions. They should also bear a description of each mode of operation of the systems in each identifiable operational state, including any emergency scenarios and their development and application in the design
(c) Manning levels and Operator competencies / authorisations required.
(d) Indication of whether or not alternative design assessment is being sought, if the proposed design deviates from the specified guidance identified in these Rules.

The System Operational Concept is to be agreed by the designer and Owner, *see also Vol 3, Pt 3, Ch 1, 2.3 Documentation required for design review 2.3.2*.

3.2 Plans

3.2.1 To support the Design Disclosure and for the purposes of assessing compliance with design requirements for inspection, installation and testing; guidance on the plans and details to be submitted for assessment review are detailed in *Vol 3, Pt 3, Ch 5, 3.2 Plans 3.2.2* and *Vol 3, Pt 3, Ch 5, 3.2 Plans 3.2.3*.

3.2.2 For navigation, the following information:

(a) Schematic plan of ship-wide navigation systems.
(b) Detailed description of navigation systems operation.

3.2.3 For communication, the following information:

(a) Schematic plan of ship-wide communication systems.
(b) Detailed description of communication systems operation.

■ Section 4 General requirements

4.1 The Rules

4.1.1 The requirements are arranged in terms of four fundamental objectives which all contribute to the overall performance of safety of navigation and communications arrangements, *see Vol 3, Pt 3, Ch 5, 4.2 Safety of navigation and communications objectives*.

4.1.2 Each of these four objectives has a series of Rule requirements attributed to them, these Rules are arranged in a 'top-down' manner such that the objective is stated as the highest level requirement. At the next level, a goal or series of goals, are detailed; the goals are then developed as performance requirement; and ultimately specified guidance.

4.1.3 In general, a system is to be compliant with the*SOLAS - International Convention for the Safety of Life at Sea* convention; however where this cannot be achieved, the performance criteria, goals and objectives are to be satisfied by assignment of a Concession or through the application of an Alternative Design Justification Report, *see* the *Naval Survey Guidance*. The referenced SOLAS Regulations to satisfy different goals are provided for guidance purposes. Alternative standards consistent with the overall SOLAS philosophy can be applied where the compliance with the objective can be demonstrated to an equivalent level to those in SOLAS.

4.2 Safety of navigation and communications objectives

4.2.1 The safety of navigation and communications objectives to be satisfied by all ships is as follows:

(a) **Communication Objective**. Every ship is to be capable of communication to avert unnecessary danger to itself and other ships in the vicinity during normal and emergency conditions, *see Vol 3, Pt 3, Ch 5, 5 Safety of communication*.

(b) **Safety of Navigation Objective**. Every ship is to be arranged with the necessary equipment to facilitate safe and effective navigation, *see Vol 3, Pt 3, Ch 5, 6 Safety of navigation*.

(c) **Equipment Arrangements Objective**. All navigation and communications equipment is to be arranged to allow safe and effective task performance, *see Vol 3, Pt 3, Ch 5, 7 Safety of navigating and communication equipment arrangements*.

■ Section 5 Safety of communication

5.1 Communication objective

5.1.1 Every ship is to be capable of communication to avert unnecessary danger to itself and other ships in its vicinity. The Communication Goal in *Vol 3, Pt 3, Ch 5, 5.1 Communication objective 5.1.8* may be achieved by the application of the referenced *SOLAS - International Convention for the Safety of Life at Sea* Regulation which is provided for guidance purposes. *See also Vol 3, Pt 3, Ch 5, 4.1 The Rules 4.1.3*.

5.1.2 **Communication Goal 1**. Every ship is to be capable of transmitting ship-to-shore distress alerts during all normal operation and foreseeable failure conditions.

5.1.3 **Communication Goal 2**. Every ship is to be capable of receiving shore-to-ship distress alerts during all normal operating conditions.

5.1.4 **Communication Goal 3**. Every ship is to be capable of transmitting and receiving ship-to-ship distress alerts during all normal operating conditions.

5.1.5 **Communication Goal 4**. Every ship is to be capable of transmitting and receiving search and rescue coordinating communications during all normal operating conditions.

5.1.6 **Communication Goal 5**. Every ship is to be capable of receiving on-scene communications during normal operating conditions.

5.1.7 **Communication Goal 6**. Every ship is to be capable of transmitting and receiving signals for the purposes of locating mobile units and individuals in distress.

5.1.8 **Communication Goal 7**. Every ship is to be capable of transmitting and receiving maritime safety information during normal operating conditions:

In general the requirements of SOLAS Chapter V, *Regulation 32 - Information required in danger messages* and *Regulation 33 - Distress situations: obligations and procedures* are to be applied.

5.1.9 **Communication Goal 8**. Every ship is to be capable of transmitting and receiving general radio-communications to and from shore-based radio systems or networks where available.

■ *Section 6*
Safety of navigation

6.1 Navigation objective

6.1.1 Every ship is to be arranged with the necessary equipment to facilitate safe and effective navigation. The Navigation Goals described in *Vol 3, Pt 3, Ch 5, 6.1 Navigation objective 6.1.2*, *Vol 3, Pt 3, Ch 5, 6.1 Navigation objective 6.1.5*, *Vol 3, Pt 3, Ch 5, 6.1 Navigation objective 6.1.6*, *Vol 3, Pt 3, Ch 5, 6.1 Navigation objective 6.1.7* and *Vol 3, Pt 3, Ch 5, 6.1 Navigation objective 6.1.8* may be achieved by the application of the referenced *SOLAS - International Convention for the Safety of Life at Sea* Regulations which are provided for guidance purposes. *See also Vol 3, Pt 3, Ch 5, 4.1 The Rules 4.1.3*.

6.1.2 **Navigation Goal 1**. Each ship is to be fitted with a means for the helmsman to determine ship track and heading at the normal place of steering during normal operating and foreseeable failure conditions:

In general, the requirements of SOLAS Chapter V, *Regulation 24 - Use of heading and/or track control systems* and *Regulation 25 - Operation of steering gear* are to be complied with.

6.1.3 **Navigation Goal 2**. There is to be adequate means of communication between any ship control and navigating stations.

6.1.4 **Navigation Goal 3**. There is to be a means of taking bearings as nearly as practicable over the arc of the horizon of 360°.

6.1.5 **Navigation Goal 4**. The ship’s steering gear is to be tested in accordance with SOLAS Chapter V, *Regulation 26 - Steering gear: testing and drills* as applicable.

6.1.6 **Navigation Goal 5**. Where the ship is likely to use a pilot to navigate certain waterways, then arrangements on board are to be sufficient safely to embark and disembark the pilot:

In general, the requirements of SOLAS Chapter V, *Regulation 23 - Pilot transfer arrangements* are to be complied with.

6.1.7 **Navigation Goal 6**. Every ship is to be equipped with all necessary publications to facilitate safe navigation:

The requirements of SOLAS Chapter V, *Regulation 27 - Nautical charts and nautical publications*, *Regulation 28 - Records of navigational activities and daily reporting*, *Regulation 30 - Operational limitations* and *Regulation 34 - Safe navigation and avoidance of dangerous situations* are to be applied as necessary.

6.1.8 **Navigation Goal 7**. Each ship is to be provided with requirements for shipborne navigational systems and equipment:

The requirements of SOLAS Chapter V, *Regulation 19 - Carriage requirements for shipborne navigational systems and equipment* and *Regulation 20 - Voyage data recorders1* are to be applied as applicable.

■ *Section 7*
Safety of navigating and communication equipment arrangements

7.1 Equipment arrangements objective

7.1.1 All navigation and communications equipment is to be arranged to allow safe and effective task performance. The Equipment Arrangements Goals described in*Vol 3, Pt 3, Ch 5, 7.1 Equipment arrangements objective 7.1.2*, *Vol 3, Pt 3, Ch 5, 7.1 Equipment arrangements objective 7.1.3*, *Vol 3, Pt 3, Ch 5, 7.1 Equipment arrangements objective 7.1.5* and *Vol 3, Pt 3, Ch 5, 7.1*

Equipment arrangements objective 7.1.6 may be achieved by the application of the referred *SOLAS - International Convention for the Safety of Life at Sea* regulations which are provided for guidance purposes. *See also Vol 3, Pt 3, Ch 5, 4.1 The Rules 4.1.3*.

7.1.2 **Equipment Arrangements Goal 1**. The navigational bridge is to be arranged to allow clear visibility of all equipment needed for navigation purposes:

In general, the requirements of SOLAS Chapter V *Regulation 22 - Navigational bridge visibility* are to be complied with.

7.1.3 **Equipment Arrangements Goal 2**. All navigating and communications equipment is to be located to avoid interference that affects its proper use and so as to ensure electromagnetic compatibility and avoidance of harmful interaction with other equipment and systems:

In general, the requirements of SOLAS Chapter V, *Regulation 17 - Electromagnetic compatibility* are to be complied with.

7.1.4 **Equipment Arrangements Goal 3**. All navigating and communications equipment is to be located to avoid the harmful effects of water, extremes of temperature and other environmental conditions.

7.1.5 **Equipment Arrangements Goal 4**. All navigation and communications equipment is to be arranged so as it remains functional in all foreseeable failure conditions:

(a) In general, all communication equipment is to be in accordance with the requirements of SOLAS Chapter IV, Part C, *Regulation 6 - Radio installations*, *Regulation 15 - Maintenance requirements*, *Regulation 16 - Radio personnel* and *Regulation 17 - Radio records*.
(b) In general, the bridge is to be arranged in accordance with SOLAS Chapter V, *Regulation 15 - Principles relating to bridge design, design and arrangement of navigational systems and equipment and bridge procedures*.

7.1.6 **Equipment Arrangements Goal 5**. All navigation equipment is to be maintained to ensure that it remains in an efficient working order:

In general, equipment is to be maintained in accordance with SOLAS Chapter V, *Regulation 16 - Maintenance of equipment*.

■ *Section 1* Scope

1.1 Philosophy

1.1.1 The purpose of this Chapter is to provide a methodology for confirming that a naval ship meets the applicable requirements of the International Maritime Organisation's Conventions for the protection of the environment.

1.1.2 Compliance with this Chapter is optional. A ship meeting the requirements of this Chapter will be eligible for an appropriate class notation, which will be recorded in the *Register Book*.

1.1.3 This Chapter details the Regulations of those Conventions that are applicable to naval ships for the purposes of these Rules, and details how these are to be complied with.

1.2 Application

1.2.1 The requirements of this Chapter are to be applied where a Certificate of Compliance or Class Notation for Pollution Prevention (**POL**) is requested.

1.2.2 As a minimum, compliance with the requirements of **POL (I,AFS)** is to be satisfied as a prerequisite for the **ENV** notation included in *Vol 3, Pt 2, Ch 2 Environmental Protection*.

1.3 Structure of the notation

1.3.1 Where all applicable Conventions are currently complied with, the notation **POL** will be eligible for a 'Star' endorsement to indicate that the arrangements on board are in accordance with National Administration requirements. This does not necessarily denote automatic endorsement by the National Administration. The 'Star' endorsement indicates full compliance with all current applicable Conventions in force as applied to commercial vessels registered with a Flag Administration, based on the dates indicated in the Conventions. Characters representing all of the applicable Conventions are included in brackets, e.g. **(I, IV, V, VI, AFS)**. Agreed Exceptions would be allowed with this notation; however, the 'Star' endorsement would not be assigned if an Exemption has been agreed, *see Vol 1, Pt 1, Ch 2, 3.2 Tailoring – Departures from the Rules and Rule additions*.

1.3.2 Where a ship is not fully compliant with all relevant requirements of the Conventions, the **POL** notation will be assigned without the 'Star' endorsement. Only those characters that represent the Conventions with which the ship currently complies will be assigned. The keel laying date will be used as the Date of Application. Agreed Exceptions would be allowed with this notation; however, a convention character would not be assigned if an Exemption has been agreed or the convention implementation dates have not been complied with.

1.3.3 The applicable convention characters are shown in *Table 6.1.1 Convention characters available with POL notation*.

Table 6.1.1 Convention characters available with POL notation

POL convention character	Description
I	Compliance with MARPOL *Annex I of MARPOL 73/78Regulations for the Prevention of Pollution by Oil* Oil pollution
II	Compliance with MARPOL *Annex II of MARPOL 73/78Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk* where ships carry chemical cargoes in bulk. Replenishment tankers carrying substances other than fuel oils
III	Compliance with MARPOL *Annex III of MARPOL 73/78Regulations for the Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form* where ships carry dangerous goods in packaged form. Replenishment stores ships
IV	Compliance with MARPOL *Annex IV of MARPOL 73/78Regulations for the Prevention of Pollution by Sewage from Ships* Sewage
V	Compliance with MARPOL *Annex V of MARPOL 73/78Regulations for the Prevention of Pollution by Garbage from Ships* Garbage
VI	Compliance with MARPOL *Annex VI - Regulations for the Prevention of Air Pollution from Ships*Emissions to Air
AFS	Compliance with *AFS - International Convention on the Control of Harmful Anti-Fouling Systems on Ships, 2001*

1.4 Ongoing maintenance of the notation

1.4.1 Once awarded, the notation will remain assigned. However, when retrospective legislation, such as the Ballast Water Management Convention, comes into force, the ship will require assessment for compliance. If the convention requirements are met, the applicable convention character would be applied (e.g. **BWM**). If the convention requirements are not met then the 'Star' endorsement would be removed if currently assigned.

■ *Section 2*
Requirements for pollution prevention arrangements

2.1 General requirements

2.1.1 The Pollution Prevention Notation **POL** notation will be assigned to vessels that demonstrate that the provision equipment and procedures on board are in accordance with the requirements of *Vol 3, Pt 3, Ch 6, 4 Prevention of pollution by oil and garbage* of these Rules.

2.1.2 Where the **POL** notation is to be assigned, an **LMC** notation must have been assigned, see *Vol 3, Pt 3, Ch 1, 1.1 Application 1.1.2*.

■ *Section 3*
Documentation required for design review

3.1 System Design Description

3.1.1 The design intent of any pollution prevention system required by the regulations is to be submitted and is to include all necessary supporting information with:

(a) The required class notation, **POL**, indicating either that the ship intends to comply with all applicable IMO Conventions for the protection of the environment (and hence would be eligible for the 'Star' endorsement) or list those Conventions that the ship intends to comply with.
(b) Details of the operational profile of the ship, to include manning provisions and training levels.
(c) A description of each mode of operation of the systems in each identifiable potential pollution of the sea or air scenario.

The System Design Description is to be agreed by the designer and Owner.

3.2 Design disclosure

3.2.1 In addition to submission of an acceptable System Design Description, a Design Disclosure should be submitted to and accepted by Lloyd's Register. The Design Disclosure is to include, but not be limited to:

(a) a statement of all design standards used in the design, manufacture, installation and testing of pollution prevention equipment and systems;
(b) a proposed list of all surveyable items together with any additional recommendations from equipment/component manufacturers. Evidence is also to be provided that all surveyable items of equipment have approval certificates;
(c) details of the proposed survey and maintenance regime;
(d) evidence of compliance with the Objectives and Goals defined in *Vol 3, Pt 3, Ch 6, 4 Prevention of pollution by oil and garbage*. This may be in the form of compliance with prescriptive Rules, Concessions, Alternative Design Justification Reports or an acceptable combination of all three, *see also Vol 3, Pt 3, Ch 1, 2.3 Documentation required for design review* and *Vol 3, Pt 3, Ch 1, 6 Route to conformance*;
(e) details of equipment configurations that are safe for operators and users;
(f) details of the proposed test procedure required to demonstrate functionality at the time of commissioning.

3.3 Plans

3.3.1 To support the engineering and safety justification and for the purposes of assessing compliance with design requirements, for inspection installation and testing; guidance on the plans and information to be submitted for assessment and reviews are detailed in *Vol 3, Pt 3, Ch 6, 3.3 Plans 3.3.2*.

3.3.2 For pollution prevention equipment, the following plans and information:

(a) Certificates of conformity against *MARPOL - International Convention for the Prevention of Pollution from Ships* Annexes as required by these Rules.
(b) General arrangement plans of equipment, detailing all essential parameters, capacity, flow rates, etc.

3.3.3 For arrangements of equipment the following plans and information:

(a) General arrangement plans of equipment layout, showing tanks, discharges, etc.
(b) General arrangement plans of all equipment assemblies such as oily water separators, pumps, etc.

3.3.4 For procedures, the following information:

Details of the pollution prevention procedure, to include oil record books, sewage discharge, etc.

■ *Section 4*
Prevention of pollution by oil and garbage

4.1 Applicable Regulations of MARPOL Annex I (Oil Pollution)

4.1.1 All regulations of MARPOL *Annex I of MARPOL 73/78Regulations for the Prevention of Pollution by Oil* are to be complied with.

4.2 Applicable Regulations of MARPOL Annex II (Noxious Liquid Substances in Bulk)

4.2.1 If applicable all regulations of MARPOL *Annex II of MARPOL 73/78Regulations for the Control of Pollution by Noxious Liquid Substances in Bulk* are to be complied with.

4.3 Applicable Regulations of MARPOL Annex III (Harmful Substances Carried in Packaged Form)

4.3.1 If applicable all regulations of MARPOL *Annex III of MARPOL 73/78Regulations for the Prevention of Pollution by Harmful Substances Carried by Sea in Packaged Form* are to be complied with.

4.4 Applicable Regulations of MARPOL Annex IV (Sewage)

4.4.1 All regulations of MARPOL *Annex IV of MARPOL 73/78Regulations for the Prevention of Pollution by Sewage from Ships* are to be complied with.

4.5 Applicable Regulations of MARPOL Annex V (Garbage)

4.5.1 All regulations of MARPOL *Annex V of MARPOL 73/78Regulations for the Prevention of Pollution by Garbage from Ships* are to be complied with.

4.6 Applicable Regulations of MARPOL Annex VI (Air Pollution)

4.6.1 All regulations of MARPOL *Annex VI - Regulations for the Prevention of Air Pollution from Ships* are to be complied with.

4.7 Applicable Regulations of Convention for the Control of Harmful Anti-Fouling Systems

4.7.1 All regulations of the *AFS - International Convention on the Control of Harmful Anti-Fouling Systems on Ships, 2001* Convention are to be complied with.

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